MALONE SERVICE COMPANY SUPERFUND SITE

Texas City, Texas

PHASE TWO REMEDIAL DESIGN AND REMEDIAL ACTION WORK PLAN

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LIST OF ACRONYMS AND ABBREVIATIONS

API	American Petroleum Institute
AST	Aboveground Storage Tank
ASTM	American Society for Testing and Materials
BGS	Below Ground Surface
BMP	Best Management Practice
BOD	Basis of Design
CD	Consent Decree
COC	Contaminant of Concern
CQAP	Construction Quality Assurance Plan
CY	Cubic Yard
EPA	Environmental Protection Agency
ESCs	Erosion & Sedimentation Controls
LCS/LDS	Leachate Collection System/Leachate Detection System
MCP	Malone Cooperating Parties
MSC	Malone Service Company
O&M	Operation and Maintenance
PC	Portland Cement
PCBs	Polychlorinated Biphenyls
PID	Photo Ionization Detector
PDR	Personal Data Ram
PNL	Project Navigator, Ltd.
PPE	Personal Protective Equipment
PSI	Pounds per Square Inch
QAPP	Quality Assurance Project Plan
RA	Remedial Action
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
RD/RA	Remedial Design/Remedial Action
RI	Remedial Investigation
RI/FS	Remedial Investigation and Feasibility Study
ROD	Record of Decision
SAP	Sampling and Analysis Plan
SOW	Statement of Work
SPLP	Synthetic Precipitation Leaching Procedure
SVOCs	Semivolatile Organic Compounds
TCEQ	Texas Commission on Environmental Quality
TCLP	Toxicity Characteristic Leaching Procedure
TS	Treatability Study
UCS	Unconfined Compressive Strength
USEPA	United States Environmental Protection Agency
VOCs	Volatile Organic Compounds

1.0 INTRODUCTION

ENTACT has prepared this Phase Two Remedial Design/Remedial Action (RD/RA) Work Plan (Plan) in accordance with the September 30, 2009 Record of Decision (ROD), and as required by the September 24, 2012 Consent Decree (CD) Statement of Work (SOW) between the U.S. Environmental Protection Agency (EPA) and the Malone Cooperating Parties (MCP). Consistent with the CD SOW, this Plan provides a detailed plan of action for completing the Phase Two RA at the Malone Services Company Superfund Site (Site) (CERCLIS ID # TXD980864789) in Texas City, Texas.

This Plan provides the designs and specifications for the major components of the Phase Two work, and describes the procedures and methods that will be performed to implement those designs during the Phase Two RA. The major work during Phase Two RA will include sludge solidification, soil excavation, and the design and construction of the RCRA Subtitle-C equivalent landfill cell (RCRA cell) and cover system.

The Plan includes five Appendices. Appendices A and B contain the Construction Drawings and Specifications for the RA work, respectively and Appendix C is the design report detailing results of the full scale solidification pilot study completed at the Site during the Phase One RA. Appendices D & E contain the calculation packages for the cell slope stability evaluation and Leachate Collection System/Leak Detection System (LCS/LDS) design.

1.1 OBJECTIVES AND SUMMARY OF WORK

The objective of this Plan is to describe the detailed specifications, design drawings, and other narrative information needed to complete the Phase Two RD/RA activities.

The overall remedial plan for the Site was described in the General RD/RA Work Plan (ENTACT, 2013). The General RD/RA Work Plan divided the remediation activities at the Site into three distinct RD/RA phases, followed by the Operations and Maintenance (O&M) phase and implementation of groundwater monitoring. The work scope for each of the three RD/RA phases is shown below. Phase One was subdivided into an RD and an RA phase.

Phase One RD **Design Investigation Activities**

- Baseline Topographic Survey
- Baseline Air Monitoring
- Universal Waste and Other Waste Classification (Asbestos, Mercury, PCBs, Laboratory Chemicals, etc.)
- Sludge/Oil Pit Depth and Side Slope Evaluation
- Sludge Solidification Bench Scale Treatability Study (TS)
- Slurry Wall Alignment, Sampling, & Testing Existing Soils & Mix Design
- On-Site Borrow Source Evaluation
- Cell Subgrade Evaluation
- Demolition Evaluation (Tanks & Buildings – Contents & Structural Evaluation)
- Monitoring Well Evaluation (Location, Depth, Materials of Construction)

Phase One RA **Remedial Action Activities**

- Site Mobilization & Set-Up
- Erosion & Sedimentation Controls (ESCs)
- Sludge Solidification Field Pilot Study
- Building & Tank Demolition, lab pack waste disposal
- Monitoring Well Abandonment
- Existing Sludge Pit Berm Improvements
- Slurry Wall Installation

Phase Two RD/RA **RD/RA Activities**

- Groundwater & Storm Water Evaluation & Management
- Design and Construction of the Subtitle C Equivalent Cell, Cap and Cover System
- Excavation and Placement of Impacted Soils
- Sludge Solidification, Placement, and Compaction in the RCRA cell

Phase Three RD/RA **RD/RA Activities**

- Construction of Drainage Swales & Perimeter Ditch Installation
- Establishment of Vegetation
- Injection Well Abandonment
- New Monitoring Well Installation

O&M and Groundwater Monitoring

1.2 SUPPORTING PLANS WHICH GOVERN THE RD/RA ACTIVITIES

The appendices of the General RD/RA Work Plan include the Component plans that will govern the subsequent RD/RA activities, including the Work described in this Plan. These Component Plans include:

General RD/RA Work Plan Appendix	Component Plan Title
Appendix A	Consent Decree Scope of Work (CD SOW)
Appendix B	Health and Safety Plan (HASP)
Appendix C	Air Monitoring Plan (AMP)
Appendix D	Spill Prevention, Control, and Countermeasures Plan (SPCCP)
Appendix E	Hurricane and Flooding Contingency Plan
Appendix F	Sampling and Analysis Plan (SAP)
Appendix G	Quality Assurance Project Plan (QAPP)
Appendix H	Project Management Plan (PMP)
Appendix I	Data Management Plan (DMP)
Appendix J	Permitting Plan (PP)
Appendix K	Construction Management Plan (CMP)
Appendix L	Construction Quality Assurance Plan (CQAP)
Appendix M	Storm Water Management Plan (SWMP) and Addendums

2.0 PHASE TWO RD/RA WORK PLAN COMPONENTS

On July 9, 2014, a Phase Two BOD meeting was held at the site to discuss the components of the Phase Two RD/RA work, performance standards, anticipated solidification mix designs for the various sludge areas, and soil removal guidelines. These discussion points formed the basis of design and these components have been incorporated into this Phase Two RD/RA Work Plan. Below find a discussion of the activities to be conducted during the Phase Two work.

2.1 OVERALL BASIS OF DESIGN (BOD) - PHASE TWO

The BOD for the Phase Two activities centers around four main tasks that will be completed during the Phase Two RA. These are sludge solidification and placement, soil excavation and placement, storm water and groundwater management, and construction of the RCRA cell and cover system. In order to support the design of these activities, several tasks were completed during the Phase One RD/RA. During the Phase One RA, a full-scale solidification pilot study was performed to provide information to design Phase Two solidification activities. Samples of solidified sludge were collected and analyzed for geotechnical properties for use in the RCRA cell design work. Details pertaining to the Phase One RA activities completed and planned Phase Two RA activities are described below.

1. Sludge Solidification & Placement – A full scale pilot study was conducted during the Phase One RA to verify the additives and mixing techniques described in the EPA approved treatability studies conducted by Shaw (Shaw, 2008) and ENTACT (ENTACT, Phase One RA Work Plan, Appendix C, 2013). The full scale pilot study report is included as Appendix C to this Work Plan and details the work including procedures, methodology, and test results. The pilot test successfully demonstrated the ability to achieve the performance specification for treated waste using on-site solidification methods. During the Phase Two RA, it is anticipated that approximately 260,000 cubic yards (cy) of sludge will be solidified and placed into the RCRA cell.

2. Soil Excavation & Placement – The Phase Two RA will include the excavation of approximately 140,000 cy of impacted soils located in the Cemetery Area, Maintenance Area, Tank 900 Area, Tank 800 Area, and Laydown Area. Approximately 7,000 cy of these soils will be blended with the sludge currently located in the above-ground storage tanks and API separators to aid in the solidification process. Soils without sludge-like characteristics that are not utilized in this process will be excavated, direct loaded into off-road dump trucks, and hauled to the RCRA cell for placement. Some soil may have sludge-like characteristics and may require additional handling and/or amendments prior to placement within the cell. This may require the transport of these soils to the Oil Pit, Sludge Pit, APIs, or the cell itself, depending on the area, depth, volume, and characteristics of the soils and project logistics.

3. Storm Water and Groundwater Management – The Phase Two RD includes the evaluation of management options for handling of groundwater and storm water during the Phase Two RA. The MCP has conducted extensive rehabilitation work on the two on-site injection wells and they are now operational. The MCP has also submitted an Addendum to the Storm Water Management Plan

(ENTACT, 2014) which describes the approach to storm water management in greater detail. In general, the approach includes the utilization of both permitted injection wells for the disposal of the most highly impacted groundwater and contact storm water. For management of any volume in excess of the injection well capacity, a water treatment plant will be installed and operated onsite. Water storage tanks will be installed to temporarily store water during larger rain events and will be emptied during periods of dry weather. Work will be sequenced and Best Management Practices (BMPs) such as temporary covers, berms, and other diversionary measures may be utilized to minimize the quantity of contact storm water generated during the RA.

4. Subtitle C Equivalent Cell & Cap Design and Construction – As stipulated by the ROD, the selected remedy includes the design and construction of a RCRA landfill cell which includes a geosynthetic clay liner (GCL), an 80-mil HDPE secondary geomembrane for leak detection, leak detection system (LDS) drainage layer consisting of geonet on the floor and geocomposite on the sideslopes , an 80-mil HDPE geomembrane primary, and a leachage collection system (LCS) geocomposite drainage layer . This system will include leachate collection which consists of a series of HDPE leachate collection pipes which are designed to transfer fluids to a series of leachate collection sumps which will facilitate the removal of leachate from the cell during and after construction of the cell. A RCRA cap will be constructed to cover the emplaced waste materials. The cap will include a double-sided geocomposite gas vent layer, a geosynthetic clay liner (GCL), a 40 mil LLDPE geomembrane, a geocomposite drainage layer, a 12-inch layer of protective cover soil, and a 6-inch vegetative layer (topsoil).

During the Phase One RA, samples of solidified sludge were collected and analyzed for geotechnical properties. The results of the geotechnical testing program were utilized to perform critical analyses on placed waste including slope stability calculations and leachate collection system performance evaluations.

The RCRA cell for the solidified sludge and impacted soils will reduce direct contact and inhalation of Contaminants of Concern (COCs) as well as the potential release of COCs from the sludge to surface soils, sediments, ground water, and surface water.

2.2 PHASE TWO RA ACTIVITIES

It is anticipated that once mobilization has occurred for the Phase Two RA, work will continue uninterrupted at the Site through the end of the Phase Three RA. Upon mobilization, the installation of the groundwater extraction (dewatering) system surrounding the Earthen Impoundment will be completed and the system will be operated until all the sludge contained within the Sludge and Oil Pits is removed and the areas are backfilled above the uppermost water bearing zone.

The construction of the RCRA cell is a critical path schedule component, which means that all activities related to this task must be timely completed to meet the proposed RA schedule. Upon mobilization, preparations for this work will begin immediately with the excavation and stockpiling of the Laydown Area soils, subsequent backfilling, and subgrade preparation to facilitate the construction of the RCRA

cell. Once the subgrade has been prepared and approved, the geosynthetic liner system including the leachate detection and collection systems will be installed.

This process of excavating impacted soils, backfilling the excavations to existing grade, subgrade preparation, and geosynthetics installation will continue for the other areas of the RCRA cell as cell construction progresses from west to east.

It is anticipated that the cell will be constructed in phases. Once the first section of the RCRA cell has been constructed to allow for waste placement, solidified sludge from Phase One and impacted soils will be placed in the cell. At this point, solidification operations will be ramped up to the targeted production rate of approximately 1,700 cubic yards per day and cell construction will progress ahead of solidification and emplacement operations through completion.

As areas of the cell reach design capacity, the waste will be fine-graded and the cap and cover system will be installed as soon as practicable.

2.2.1 Mobilization and Dewatering Startup

The installation of the dewatering system and the construction of the slurry wall were completed during the Phase One Remedial Action. The Site injection wells were also rehabilitated. This work was implemented to provide more flexibility in managing groundwater at the Site by utilizing the injection wells for the disposal of groundwater anticipated from the dewatering system. The dewatering system will be started up and operated continually upon mobilization for Phase Two work and prior to full scale solidification activities. This timing will maximize the drawdown of groundwater prior to solidification of sludge. Further, once dewatering rates have declined over time, this increases injection well capacity to accept contact storm water.

2.2.2 Air Monitoring

During the Phase One RA, personal, work area, and perimeter air monitoring was conducted in accordance with the Health & Safety Plan and Air Monitoring Plan included as Appendices A and C of the approved General RD/RA Work Plan. The results of personal air monitoring conducted during pilot sludge solidification activities were analyzed to determine PPE requirements for proposed Phase Two RA activities. It is anticipated that workers will perform their work in Level D or Level D modified PPE while continuing to perform routine air monitoring as required by the approved plans which will consist of personal, work area, and site perimeter monitoring which is discussed in the following sections.

2.2.2.1 Personal Air Monitoring

Personal air monitoring will be performed as specified in the site-specific HASP included as Appendix B of the General RD/RA Work Plan. Samples will be collected daily over the course of soil/sludge handling activities using organic vapor monitors for VOCs. A photoionization detector (PID) and PDR will also provide real-time measurements of VOCs and particulates during high risk work tasks. Sustained

VOC readings on the PID of greater than 10 ppm in the worker breathing zone for longer than 15 minutes will require the use of colorimetric indicator tubes to determine if the reading is caused by the presence of benzene. If benzene is present at concentrations greater than 0.5 ppm, work will be stopped until the levels subside, engineering controls are established, or an appropriate upgrade in PPE is implemented. If elevated levels of dust are measured at or above the exposure limit, engineering controls will be implemented. These may consist of a modification in the task being performed or the implementation of dust control measures consisting of the use of water being sprayed from low pressure nozzles.

2.2.2.2 Work Area Monitoring

Work area air monitoring will be performed with portable, real-time or direct monitors including PDRs and 4-Gas meters with PID capabilities at various locations across the site. Work area monitoring will be performed utilizing a PDR and 4-Gas meter with PID at one location upwind and one location downwind from the active work area. Monitoring will be performed and data continuously recorded each day that intrusive activities are being performed.

2.2.2.3 Perimeter Air Monitoring

Perimeter monitoring and data recording will be conducted continuously at both upwind and downwind locations around the site during intrusive work activities. The stations will be moved if the wind direction differs significantly during multiple days of work activity. The perimeter air monitoring stations will not be operated during heavy rain events. The downwind station will house a photoionization detector (PID) with alarm, a personal sampling pump for PAH sampling, and a total dust monitor (PDR). Both the PID and PDR will provide real-time information with data recording capabilities. PAH samples will require off-site analysis. The upwind air monitoring station will contain a PID and PDR, both with data recording capabilities. The perimeter sampling frequency for the PDR will be on a daily basis for the duration of intrusive activities while the frequency for the PID and PAH sampling will be on a daily basis during impacted soil/sludge handling activities. The PID and PDR will be checked at least twice daily (AM and PM) by the on-Site Health and Safety Officer or Quality Control Officer to ensure correct operation and to determine if airborne action levels are being exceeded. Additional checks will be performed in the event real time actions levels are exceeded in an active work area.

2.2.3 Completion of Remaining Phase One Work

In order to complete the Phase Two RA, completion of work previously proposed for Phase One will be performed during the course of the work since some of these tasks are interrelated and must be performed concurrently. Specifically, once the sludge is removed from the remaining aboveground tanks, demolition activities will continue with the removal/recycling of the steel storage tanks and the removal of the concrete slabs located beneath the tanks. Demolition work and other previous Phase One activities will follow the requirements detailed in the Phase One RA Work Plan.

2.2.4 Sludge Solidification

It is anticipated that approximately 260,000 cy of sludge located in four main areas of the Site will require solidification prior to placement into the cell. The areas and estimated volumes are listed in the following table.

Anticipated Solidification Volume Table

Sludge Area	Approximate Volume to be Solidified (CY)
Sludge Pit	200,000
Oil Pit	40,000
API Separators	10,000
Tank Sludge	10,000
Total:	**260,000**

The solidification of sludge will require the use of tracked excavators to mechanically mix the required reagents into the sludge beginning with fly ash (when utilized), followed by quick lime, and finally Portland cement). This method utilizes dry reagents delivered in pneumatic tankers and/or end dump trailers and an approach that requires the sludge to be solidified in batches of 250 to 500 cy in volume. It is anticipated that up to six tracked excavators will be performing solidification during full-scale operations completing a total of up to 2,000 cy of solidification per day over a period of approximately ten months. Once the solidified sludge has reached the required unconfined compressive strength (UCS) while exhibiting no free liquids, it will be excavated, transported, and placed into the RCRA cell for disposal. Additional details on the specific areas are discussed below.

2.2.4.1 Performance Standard

The performance goal of ENTACT's full-scale solidification pilot study performed during the Phase One RA was to confirm a reagent mixture capable of creating a solidified material with a minimum UCS of 15 psi with all samples meeting an average of at least 25 psi (per ASTM D2166) while expressing no free liquids during UCS testing, within 28 days. As reported in Appendix C, the full-scale solidification pilot study confirmed and demonstrated that the required strength and absence of free moisture requirements can be met in the field utilizing the same equipment and techniques anticipated for use during the remedial action. During full scale solidification operations, testing will be completed per the requirements listed in Specification Section 02210 in Appendix B to this Work Plan and the Construction Quality Assurance Plan (CQAP) included as Appendix L of the General RD/RA Work Plan.

On October 16, 2014, the MCP submitted a request to EPA to approve a modified performance criterion for treated material of a minimum of 15 psi (per ASTM D2166) while expressing no free liquids during UCS testing. EPA has approved this change, and formal approval is pending.

2.2.4.2 Sludge Pit

Due to the depth of the Sludge Pit (up to 40 ft), solidifying the material to full depth in single passes using dry reagent and traditional long-stick excavators is not practical or safe. ENTACT has therefore developed a staged approach to the solidification in the Sludge Pit. The approach includes solidification of an initial set of perimeter batches (where the sludge is fairly shallow) followed by a secondary (lowering) step which involves bailing sludge from the deeper areas from the center of the Sludge Pit into bins constructed on top of the previously treated perimeter batches for subsequent solidification. Once the material has been solidified and removed to a depth of approximately 14 ft, the remainder of the solidification will then be completed in-situ. Figure 19 included in Appendix A to this Work Plan shows a conceptual depiction of the anticipated process. Each stage of the solidification process will be followed by sample collection testing, excavation, and placement in the cell in constructed lifts.

As detailed in Appendix C to this Work Plan, the Phase One Full-Scale Solidification Pilot Study Report, the solidification criterion was accomplished for the Sludge Pit materials as shown below:

Sludge Pit Formulations

Additive	Mix Design 1 Addition Rate (Percent by Weight)	Mix Design 2 Addition Rate (Percent by Weight)
Portland Cement	10	15
Quicklime	10	10
Fly Ash	20	-

One of these mix designs will be used initially, to solidify sludge pit material during the Phase Two RA, as determined by the sludge characteristics of each particular batch. ENTACT will modify these mix designs during operations as conditions in the sludge vary. The flexibility to add more or less of the noted reagents in the field allows optimization of the solidification process while minimizing retreatment. Regardless of any field adjustments of the mix design during operations, all treated material will be solidified and achieve the performance specification.

The quantity of each reagent required for each batch will be calculated based on the actual volume of sludge to be solidified per batch by first converting the designated volume to weight and multiplying this value by the required percentage of each reagent. Reagent addition will start with fly ash (when utilized), followed by quicklime, and finally Portland cement. The excavator will mix the reagents into the sludge until a homogeneous matrix is attained. Visual confirmation observed by the ENTACT onsite QA/QC Manager, will be utilized in order to verify thorough mixing from the surface to the full depth of the batch.

Immediately following the solidification of the batch, a sample location and depth will be selected. For batches less than 12 feet in depth, an excavator will be used to excavate the treated materials to the desired depth, collect a sample, and backfill the hole. For batches with thicknesses greater than 12 feet in

depth, an excavator will be used to collect a sample at the middle of the solidified interval and within approximately 3 feet of the bottom of the solidified depth which will be composited prior to testing. Approximately two gallons of solidified material will be collected from each batch and placed into a five-gallon bucket. The samples will then be prepared and tested as described in Section 2.2.4.6, Sample Preparation and Testing.

Following the receipt of successful results for a particular batch, the solidified sludge will be excavated, loaded into off-road dump trucks, and hauled to the cell for placement. The relocation of solidified sludge will be conducted continuously throughout the solidification process to provide the adequate working area for subsequent batches as the solidification process progresses lower and toward the center of the Sludge Pit. Once the majority of the sludge has been solidified and removed to approximately Elevation -5.0, the remaining sludge at the bottom of the pit will be solidified in-situ (approximately 14 ft bgs). When test results show achievement of the performance criteria for this final section, the solidified material will be excavated, loaded into dump trucks, and hauled to the cell for placement per the requirements of Specification Section 02302 included in Appendix B to this Work Plan.

Concurrent with soil removal activities, backfill excavated from the borrow area will be loaded, hauled, and placed into the excavated pit per the requirements of Specification Section 02200 included in Appendix B. Backfilling operations will continue until soil is placed above the level of the groundwater table.

2.2.4.3 Oil Pit

The Oil Pit is approximately 35 feet in depth and will require a combination of in-situ and ex-situ techniques. Drawing #20 included in Appendix A shows a conceptual depiction of the anticipated solidification process in this area which includes solidifying the upper section of sludge and overburden first, followed by in-situ solidification of the lower section. Similar to the technique anticipated for the Sludge Pit, it is also expected that a lowering step may also be necessary whereby sludge is bailed from the center of the Oil Pit into bins constructed on top of previously treated perimeter batches for subsequent solidification. The following mix design was utilized during the full-scale pilot study to successfully demonstrate the solidification criterion could be met on a full-scale basis within the Oil Pit:

Oil Pit Formulation

Additive	Addition Rate (Percent by Weight)
Portland Cement	5
Quicklime	5
Fly Ash	20

This mix design will be utilized initially to solidify Oil Pit sludge during the Phase Two RA. ENTACT will modify this mix design during operations as conditions in the field change. The flexibility to add more or less of the noted reagents in the field allows optimization of the solidification process while

minimizing retreatment. Regardless of any adjustments to the mix design during operations, all treated material will be solidified and achieve the performance specification.

The quantity of each reagent required for each batch will be calculated based on the actual volume of sludge to be solidified per batch by first converting the volume of the batch to weight and multiplying this value by the required percentage of each reagent. Reagent addition will start with fly ash, and be followed by quicklime, and finally Portland cement. The excavator will mix the reagents into the sludge until a homogeneous matrix is attained. Visual confirmation observed by the ENTACT onsite QA/QC Manager, will be utilized in order to verify thorough mixing from the surface to the full depth of treatment (bottom of the Oil Pit). A sample location and depth will be selected once the batch is thoroughly mixed from top to bottom and deemed complete. For batches less than 12 feet in depth, an excavator will be used to excavate the treated materials to the desired depth, collect a sample, and backfill the hole. For batches with thicknesses greater than 12 feet in depth, an excavator will be used to collect a sample at the middle of the solidified interval and within approximately 3 feet of the bottom of the solidified depth which will be composited prior to testing. Approximately two gallons of solidified material will be collected and placed into a five-gallon bucket. The samples will then be prepared and tested as described in Section 2.2.4.6.

When test results show achievement of the performance criteria, the solidified sludge will be excavated, loaded into off-road dump trucks, and hauled to the cell for placement. The relocation of solidified sludge will be conducted continuously throughout the solidification process to provide the adequate working area for subsequent batches as the solidification process progresses lower and toward the center of the Oil Pit. Once the majority of the sludge has been solidified and removed to approximately Elevation -5.0, the remaining sludge at the bottom of the pit will be solidified in-situ (approximately 14 ft bgs). As successful results are obtained on this final section, the solidified material will be excavated, loaded into dump trucks, and hauled to the cell for placement per the requirements of Specification Section 02302 included in Appendix B. Concurrent with soil removal activities, backfill excavated from the borrow area will be loaded, hauled, and placed into the excavated pit per the requirements of Specification Section 02200 included in Appendix B. Backfilling operations will continue until soil is placed above the level of the groundwater table.

2.2.4.4 API Separators

The following mix design is anticipated to be initially used for the solidification of sludge within the API Separators:

API Separator Formulation

Additive	Addition Rate (Percent by Weight)
Portland Cement	15
Quicklime	15
Fly Ash	30
Site Soils	50

ENTACT will modify this mix design during operations as conditions in the field change. The flexibility to add more or less of the noted reagents in the field allows optimization of the solidification process while minimizing retreatment. Regardless of any adjustments to the mix design during operations, all treated material will be solidified and achieve the performance specification.

The two API Separators contain a total of approximately 10,000 cy of sludge that requires solidification. In each of the separators, any standing water will first be removed and disposed of in one of the two onsite injection wells. The impacted soils to be added to the API Separator sludge will then be excavated from one of the soil excavation areas and transported to the API Separator. An excavator will first mix the soils into the sludge to absorb excess moisture in preparation for the addition of dry reagents. Reagent addition will then follow starting with fly ash, quicklime, and finally Portland cement. The excavator will mix the reagents into the sludge until a homogeneous matrix is attained. Visual confirmation observed by the ENTACT onsite QA/QC Manager, will be utilized in order to verify thorough mixing from the surface to the full depth of the batch. A sample location and depth will be selected once the batch is thoroughly mixed from top to bottom and deemed complete. An excavator will be used to excavate the treated materials to the desired depth and collect a sample. Approximately two gallons of solidified material will be collected and placed into a five-gallon bucket. The samples will then be prepared and tested as described in Section 2.2.4.6.

When test results show achievement of the performance criteria, the solidified sludge will be excavated, loaded into off-road dump trucks, and hauled to the cell for placement. The empty API Separators will then be utilized for the storage of contact storm water as necessary throughout the remaining duration of the Phase Two RA. Once no longer needed, any above-grade concrete will be removed and hauled to the RCRA cell for disposal while concrete below-grade will be decontaminated and the area backfilled up to existing grade utilizing soil excavated and hauled from the borrow area.

2.2.4.5 Tank Sludge

The following initial mix design is anticipated to be used for the solidification of sludge within the Tanks:

Tank Sludge Formulation

Additive	Addition Rate (Percent by Weight)
Portland Cement	20
Quicklime	20
Fly Ash	30
Site Soils	50

ENTACT will modify this mix design during operations as conditions in the field change. The flexibility to add more or less of the noted reagents in the field allows optimization of the solidification process

while minimizing retreatment. Regardless of any adjustments to the mix design during operations, all treated material will be solidified and achieve the performance specification.

To the extent practicable, any water that may have accumulated in the tanks will be removed and disposed of in one of the onsite injection wells prior to initiating solidification activities. Impacted soils will then be excavated from one of the soil excavation areas and transported to the tank areas for incorporation into the sludge. In some cases where the sludge depth is fairly shallow, the mixing may occur inside the tank. This will require the use of an excavator-mounted shear to first remove the roof and upper sections of the tank, prior to the addition of site soils and reagents. In other instances, the mixing will occur within the bermed area surrounding the tank. In both cases, an excavator will first mix the site soils into the sludge to absorb excess moisture in preparation for the addition of dry reagents. Next, reagents will be added starting with fly ash, followed by quicklime, and finally Portland cement. The excavator will mix the reagents into the sludge until a homogeneous matrix is attained. Visual confirmation observed by the ENTACT onsite QA/QC Manager, observed by the ENTACT onsite QA/QC Manager, will be utilized in order to verify thorough mixing from the surface to the full depth of the batch. A sample location and depth will be selected once the batch is thoroughly mixed from top to bottom and deemed complete. An excavator will be used to excavate the treated materials to the desired depth and collect a sample. Approximately two gallons of solidified material will be collected and placed into a five-gallon bucket. The samples will then be prepared and tested as described in Section 2.2.4.6.

When test results show achievement of the performance criteria, the solidified sludge will be excavated, loaded into off-road dump trucks, and hauled to the cell for placement. The empty tanks will then be decontaminated and demolished per the requirements of the approved Phase One RA Work Plan. This will involve cutting apart the steel tanks to permit the transportation of the pieces to an offsite recycling facility. The concrete pads beneath the tanks will also be demolished and, depending on whether the concrete is visually impacted, either placed into the cell for disposal or staged for later use as riprap armoring on the sideslopes of the Bay side of the RCRA cell.

2.2.4.6 Sample Preparation and Testing

Sample cylinders will be prepared in the field in the same manner as was completed in the field during the full-scale solidification pilot study. Solidified sludge will be placed into 3 inch by 6 inch right cylinder molds in lifts and compacted with a stainless steel rod to remove all air voids. A minimum of four cylinders will be prepared for each batch of 250 to 500 cy to provide enough samples for the required testing with three spares. Once collected and prepared, samples will be labeled with the date, time, area, and grid number and will be placed in Ziplock bags. Once sufficiently cured, samples will be tested for UCS per ASTM D2166 as required by the CQAP.

Prior to UCS testing, filter paper will be placed on top and below each cylinder to analyze the presence of free liquids. The presence of free liquids will be documented in terms of a yes/no – liquid present/liquid absent on each cylinder that is broken.

It is anticipated that some solidified batches will reach the minimum of 15 psi in less than 28 days. In these instances, the results will be documented with penetrometer and/or UCS testing data on these batches prior to the placement of material into the cell.

In the event that a particular batch does not meet the minimum UCS requirements or exhibits free liquids during UCS testing, the batch will be re-solidified and tested utilizing the same criteria. If necessary, water may be added to assist in the hydration of the reagents utilized when re-treating a failed batch.

2.2.4.7 Solidified Sludge Placement

Prior to full-scale waste placement and compaction in the cell, the solidified Sludge Pit waste will be subject to a test fill program which will be utilized to evaluate the compaction effort required for the solidified sludge to reach the minimum required density of 90 percent utilizing a standard proctor test. The test fill will be constructed using representative solidified Sludge Pit waste that has achieved its designated unconfined compressive strength (UCS) and then has been excavated (thereby breaking up the solidified material) and transported to a test fill area of the lined cell. The test fill will be placed and compacted using the same equipment and procedures proposed for use during full-scale operations. The details of the required test fill are included in Specification Section 02302 in Appendix B. The test fill program will identify equipment types, placement and compaction techniques, moisture conditioning methods if any, lift thickness, and number of passes necessary to achieve the minimum compaction requirements. These methods will then be required for full-scale waste placement operations for the remaining of the solidified sludge waste materials.

Following achievement of the performance criterion, solidified sludge will be loaded into off-road dump trucks and transported directly into the RCRA cell for placement. Solidified sludge will be placed utilizing bulldozers in lifts and compacted to meet a minimum of 90% of its standard proctor dry density utilizing methods approved during the test fill program. During solidified sludge placement, materials will be placed in a manner that minimizes the accumulation of storm water by controlling grade and allowing contact storm water to drain towards the sumps and laterals installed during the RCRA cell construction or towards localized sumps to facilitate removal. Prior to anticipated precipitation events, solidified sludge located within the cell will be compacted utilizing a smooth-drum roller to minimize infiltration and areas where water can accumulate.

2.2.5 Soil Excavation and Placement

Surface and subsurface soil will be removed from the locations at the Site that were identified during the RI, as shown in the ROD (*ROD, Figure 3*). The locations include areas in the Laydown Area, Cemetery Area, Unit 800 Area, Unit 900 Area, and Maintenance Area Pits. The areas for removal are shown on Drawing #21 in Appendix A and in the table below.

Soil Excavation Areas

Area	Surface Area(sf)
Laydown Area	557,477
Cemetery Area	43,512
Maintenance Area-Pits	85,795
Maintenance Area-900 Tank Area	11,277
Unit 800 Tank Area	118,709
Shallow Removal Areas	52,262

Consistent with the ROD, soil excavations will remove source material and soil over the surface soil remediation levels, but the excavations will extend vertically no deeper than to the top of the uppermost water bearing zone. The soil excavation is intended to protect anticipated exposure routes as described in the ROD and is not intended as a groundwater remedy. Therefore, soil excavation will not extend into the uppermost water bearing zone. This depth of excavation is not anticipated to require extensive dewatering or shoring procedures beyond those required for unsaturated soil.

Laterally, soil will be removed to the limits as shown on Drawing #21 in Appendix A (same as Figure 3 from ROD). For source material, prior to excavation, MCP representatives, in conjunction with EPA, will delineate the lateral boundary of source material using test pits and observations to define the final lateral extent of removal of source material. Should source material be observed laterally outside of the areas shown, ENTACT will remove such material laterally above the uppermost water bearing zone, in consultation with the MCP and EPA.

Confirmation soil samples will be taken at the base of excavation areas that stop above the uppermost water bearing zone to confirm the removal of soil above the remediation goals. Sampling procedures are described in the Sampling and Analysis Plan.

Confirmation of source material removal will be visual and in consultation with EPA. The delineation work will be coordinated with EPA and documented. Documentation will be developed in conjunction with EPA and issued as an addendum to the Construction Quality Assurance Plan.

It is anticipated that the majority of these soils will be directly loaded into off-road dump trucks and transported into the cell for disposal. As discussed above, approximately 7,000 cy of these soils will be utilized during the solidification of the API and tank sludge. When being utilized for sludge solidification, these soils will be excavated and relocated to the required solidification area and incorporated in the sludge prior to the addition of reagents.

Specification Section 02302 in Appendix B details the specific requirements for the placement and compaction of excavated soil as cushion layer material, soil utilized for berm construction, and as regular waste placed within the interior sections of the cell. Soils placed into the cell is subject to specific placement procedures to ensure the completed cell is functional and stable. This will require achievement of minimum compaction standards for controlled lifts of soil placed into the cell within a range of

acceptable moisture contents based on each type of soil being placed. This may require the additional effort of disking/drying wet soils or the addition of small percentages of lime or fly ash to evaporate excess moisture prior to or during placement. Soils placed on the bottom of the cell will have additional requirements with respect to grain size and compaction as the first several feet of material placed on top of the liner will serve as the cushion layer to protect the geosynthetic system during subsequent soil/sludge placement operations. Additionally, impacted soil will be placed around the perimeter of the cell in the area adjacent to injection well WDW-073 and within the berms at each of the phase boundaries. This is necessary to provide material with the required shear strength necessary to buttress placed waste and to provide practicable staging and work areas for waste placement up to the final waste grades of the cell.

Debris placed into the cell is also subject to placement requirements. Specifically, demolition material/debris having particle sizes greater than one foot in any dimension will not be placed within two feet of the top of the protective cover layer component of the geosynthetic system. The details of these requirements are listed in Specification Section 02302 in Appendix B.

2.2.6 Design of RCRA Subtitle C-Equivalent Cell

Engineering drawings showing the layout of the RCRA Subtitle C-equivalent cell are included in Appendix A. These drawings include grading plans of the liner system subgrade, top of waste grades, and top of final cover system grades. The drawings also provide various cross sections and engineering details of the liner system, final cover system, and leachate collection system/leachate detection system (LCS/LDS) components. The anticipated RCRA cell design area and capacity are as follows:

- RCRA Cell Area (2-D plan area of the limit of liner) = 30.6 acres; and
- Waste Disposal Capacity = 575,800 cubic yards.

Drawing #4 presents the layout of the base (liner system subgrade) of the RCRA cell. It is anticipated that the RCRA cell will be developed in phases progressing in a general west to east direction, to accommodate the rate of waste solidification and the staging of the various remedial activities in and around the cell footprint. As shown on Drawing #4, four phases are designated. The phase boundaries are approximate, and may be adjusted based on the actual timing and sequencing of the work (e.g., waste placement rates, etc.).

The last phase (Phase 4) is termed a contingency area. This phase was added to the design to provide additional waste disposal capacity beyond the current estimate of the waste volumes that will be placed in the landfill, due to the uncertainty of the actual in-place waste volumes that may be generated. This contingency phase may or may not be constructed.

As cell development and waste placement are ongoing, the as-placed waste quantities will be tracked in order to refine the estimated final disposal volume, and make the decision on whether or not to construct Phase 4. The RCRA cell layout, including the slopes of the floor grades and orientation of the LCS/LDS

features (sumps, collection corridors) have been designed such that they can function with or without Phase 4, so that if Phase 4 is not constructed, the layout of the adjacent Phase 3 will not need to be revised other than to change the location of the exterior perimeter berm to follow the Phase 3 limits, and revising the final cover grades accordingly.

Drawing #5 and Drawing #6 in Appendix A present the top of waste grades and the top of final cover grades, respectively. As shown, final cover slopes are predominantly in the 2 to 4 percent range. The middle south portion of the cell has somewhat steeper slopes of up to 7 horizontal to 1 vertical (7H:1V). The final cover grades generally meet along a ridge oriented along the long axis of the cell (general east-west direction), and the peak elevation of the top of final cover system is slightly more than elevation 26 feet above mean sea level (26 ft, MSL).

The RCRA cell liner system is depicted in cross-sectional engineering details on Drawing #10 in Appendix A. As shown, base grades less than 5 percent are defined as "floor" areas, and base grades equal to or greater than 5 percent are defined as "sideslope" areas. The liner system will be composed of (from bottom to top):

- prepared subgrade consisting of a minimum of 1' of compacted clay;
- geosynthetic clay liner (GCL);
- 80-mil high-density polyethylene (HDPE) geomembrane (smooth on floor, textured on sideslopes);
- leak detection system (LDS) drainage layer consisting of:
  - a geonet (on floor areas); or
  - a double-sided geocomposite drainage layer (on sideslopes);
- 80-mil HDPE geomembrane (smooth on floor, textured on sideslopes);
- leachate collection system (LCS) drainage layer consisting of:
  - a single-sided geocomposite drainage layer (on floor areas); or
  - a double-sided geocomposite drainage layer (on sideslopes); and
- 1-ft thick protective cover layer (impacted soils).

As shown, the main difference between floor and sideslope areas is the use of either smooth geomembranes, or textured geomembranes. As a result of the geomembrane type, the adjacent drainage layers are slightly different. The reason for these differences is that textured geomembranes can provide higher interface friction between adjacent components, which is appropriate for those materials placed on sideslopes (i.e., for adequate slope stability purposes). The liner system components have been selected and designed to be stable, allow for adequate collection and removal of liquids (LCS and LDS drainage layers), provide a double-liner system barrier to prevent migration of wastes out of the landfill, and have sufficient chemical properties, strength, and thickness to prevent failure due to anticipated pressures and stresses.

2.2.6.1 Geotechnical Properties of Foundation Soils and Perimeter Berms

The Preliminary Site Characterization Report (PSCR) (2004) describes the underlying soils (foundation soils) at the site. In general, the subsurface soil is clay (CL or CH) with three non-contiguous transmissive zones of interbedded clay, sand, and silt (CL, SC, SM, or ML) mixtures (Figures 10-17 in Remedial Investigation (RI) (2006), as follows:

- The upper zone (identified as TZ-1 in the PSCR) is about 10 feet below ground surface (bgs) and ranges in thickness from 0 to 8 feet.
- The second zone (TZ-2) is about 18 to 28 feet bgs, ranges in thickness from 0 to 12 feet, and consists of silty clay, silty sand, and silt.
- The deeper zone (TZ-3) is about 35 to 48 feet bgs, ranges in thickness from 0 to 14 feet, and consists of silt, silty sand, and sandy clay.

In addition to the three transmissive zones listed above, the PSCR describes a buried paleochannel, or sand channel, that meanders across the site (Figure 18 in RI (2006). The paleochannel is found about 10 feet bgs and is about 20 feet thick. It typically consists of tan, fairly uniform, very fine-grained, silty sand.

In order to assign geotechnical material properties to the site soils, Geosyntec used information from the PSCR, supplemented by site investigations previously performed at the adjacent Campbell Bayou Facility (CBF) (a site for which Geosyntec recently served as the landfill permit design engineer-of-record). Laboratory tests relevant to these analyses that were conducted as part of one or more of these investigations include: grain size analysis and/or percent passing No. 200 sieve, Atterberg limits, USCS soil classification, moisture content, dry unit weight, direct shear, unconsolidated undrained, and consolidated undrained. These properties are summarized in the slope stability calculation package presented in Appendix D to this Work Plan.

It is anticipated that the existing berms on the north, west, and east side of the site will remain in place and will be utilized as perimeter berms for the RCRA cell. In general it appears that compacted clay was used for the construction of the existing berms and typical strength properties of compacted clay from correlations presented in technical literature were used in the slope stability analyses.

2.2.6.2 Geotechnical Properties of Waste

As part of the RCRA cell design activities, the geotechnical properties of the waste types that will be disposed of in the cell were evaluated to support slope stability analyses and to evaluate leachate collection system performance and related drainage layer design.

The waste will be composed of stabilized sludges (from the Sludge Pit, Oil Pit, API Separators, and Tank Sludge), surface soils, and building debris. The largest quantity of waste will be Sludge Pit material stabilized with reagents. The next largest waste type will be surface soils. The third largest waste type

will be Oil Pit sludge stabilized with reagents. Together, these three main waste types are estimated to comprise approximately 90 percent of the total waste volume.

For the surface soils, the geotechnical strength properties can be estimated in a straightforward manner using information from site boring logs, soil classifications, etc., and based on conventional geotechnical correlations. However, the wastes that will be disposed of in the RCRA cell will be site-specific and their geotechnical properties (e.g., strength and permeability) will depend on the stabilization mix design. Therefore, a site-specific geotechnical laboratory testing program was performed in August 2014, using the Sludge Pit and Oil Pit mixtures that achieved the minimum desired unconfined compression strength (UCS) of 15 psi. To appropriately simulate field conditions expected to result from excavating the in-situ stabilized waste material, transporting it to the RCRA cell, and compacting it in the cell, the stabilized material lab specimens were broken into soil-sized fragments prior to the geotechnical testing. The resulting mixes were soil-like in appearance, resembling silty sand with trace clay. Then, the specimens were testing by a geotechnical laboratory, in accordance with American Society of Testing and Materials (ASTM) standards, to measure the following properties:

- Grain Size Distribution;
- Atterberg Limits;
- Unified Soil Classification System (USCS) Classification;
- Standard Proctor Compaction (Moisture-Density) Relationship;
- Hydraulic Conductivity; and
- Direct Shear (Shear Strength).

As mentioned, the parameters obtained from the laboratory testing program were used for the slope stability calculations, and for calculation of estimated leachate generation and related leachate collection system performance and related drainage layer design. These design activities are discussed below, and the calculation are provided in Appendices D and E, for slope stability and the LCS/LDS, respectively.

2.2.6.3 Slope Stability Evaluation

Slope stability analyses were performed for several cross sections to evaluate various applicable sliding failure scenarios at various critical configurations of the RCRA cell. Critical cross sections for analyses were chosen based on consideration of critical combinations of geometry and soil/waste properties. These slope stability analyses are presented in Appendix D. The calculations presented in this appendix include a detailed discussion of the approach, sliding scenarios, critical cross sections, assumed parameters, and results. Comprehensive calculations are presented for the relevant sliding scenarios and critical cell cross sections. The components of the RCRA cell for which the slope stability analyses were performed are:

- overall conditions for the final RCRA cell slope configuration after closure (including evaluating stability of the final capped waste, liner, and foundation soils beneath the cell);
- levee and berm slopes;

- liner system slopes prior to waste placement (i.e., liner system veneer);
- interim landfill slopes during operation (interim waste placement slopes); and
- final cover system slopes (i.e., final cover system veneer).

The approach to conducting the slope stability evaluation was to calculate the "factor of safety" (FS) for slopes involving the cell components. The factor of safety is defined as the ratio between the resisting force and the driving force. Resistance against sliding is the force that "holds the slope up" – which is provided by the strength of the materials. Driving force is the gravitational force that attempts to "pull the slope down" – due to the weight of the slope (based on the slope steepness/geometry). If the FS = 1, a slope is just stable. A FS < 1 indicates an unstable slope (one predicted to fail); and a FS > 1 indicates a stable slope (i.e., a slope where the strengths of the materials in the slope are large enough to resist the forces trying to push it down-slope). Based on the mode of sliding failure, the uncertainty of strength measurements, and the consequences of failure, the minimum target factors of safety are selected. These are discussed subsequently in this section.

For evaluation of the overall stability of the RCRA cell slopes, berms, and foundation, analyses were performed using a slope stability computer program ("SLIDE", developed by Rocscience, Inc.) that is widely used in geotechnical engineering practice. The computer program performs computations to calculate the factors of safety for thousands of potential slope failure surfaces passing through different parts of the landfill. The program then identifies the potential slope failure surface with the lowest (i.e., critical case) calculated factor of safety. The results are then compared to the target minimum acceptable factors of safety (discussed below), to check whether the stability of the slopes meets the design criteria.

For potential failure surfaces that slide along the liner system or final cover system, the approach was similar to that described above, except that the computations were performed to back-calculate the minimum strength that needs to be provided by the liner system or final cover system components that yields the acceptable target calculated factor of safety. This approach is consistent with engineering design practice for landfills, since the liner and cover system components are made up of installed /constructed products whose strength is dependent on the type of product selected and the manner in which it is constructed. The back-calculated minimum strength values for the liner system and final cover system were then incorporated into the material specifications for liner and final cover materials, so that procedures are in place to verify at the time of construction that the minimum required strengths of the liner and cover materials are met.

Minimum acceptable factors of safety for landfill slope stability depend on project-specific conditions and uncertainties. The target calculated factor of safety under interim conditions (i.e., perimeter dike slopes prior to liner system construction, liner system veneer, and interim landfill slopes during operation) is 1.25 based on recommendations in the technical literature (see Appendix D for further details and references). The target calculated factor of safety under final conditions (i.e., final cover veneer, final liner and foundation conditions, and final landfill slopes at the end of operation) is 1.5 based on the 2004 EPA Technical Guidance Document for RCRA/CERCLA Final Covers (2004) (full reference provided in

Appendix D), and considering the uncertainty of strength measurements and the consequences of failure into the factor of safety.

In contrast, for large-displacement cases considered with shear surfaces that pass along a liner or final cover system interface, target factors of safety were assigned and the minimum required large-displacement strengths producing the target factor of safety were back-calculated. The target minimum calculated factor of safety using large-displacement strengths was set as 1.0 for interim conditions and 1.15 for final conditions. This approach is consistent with (for interim conditions) and more conservative than (for final conditions) that outlined in TCEQ's Industrial Solid Waste Management "Technical Guideline No. 3 – Landfills", dated 2009, which recommends a factor of safety of 1.0 for residual strength (i.e. large displacement) conditions.

The results of the slope stability analyses indicate that the RCRA Cell as designed and specified herein has the adequate calculated factor of safety against slope stability sliding for the modes analyzed at the critical cross sections.

2.2.6.4 Leachate Collection and Leak Detection System Design

The LCS/LDS design is presented in Appendix E to this Work Plan. The following LCS and LDS-related engineering analyses were performed and are presented in sub-exhibits within Appendix E:

- Leachate Generation Rates (HELP Modeling) and Head on Liner;
- Geotextile Filter Design;
- LCS and LDS Drainage Layer Design;
- LCS and LDS Pipe Design; and
- LCS Sump Capacity Calculations.

The remainder of this section discusses the LCS and LDS design in more detail.

As shown on the liner system details on Drawing #10 in Appendix A, the liner system includes an LCS drainage layer (double-sided geocomposite on slopes >5% and single-sides geocomposite on slopes < 5%) above the primary geomembrane liner, to collect and convey leachate towards low spots (sumps) within the cell. Similarly, the proposed liner system includes an LDS drainage layer (double-sided geocomposite on slopes >5% and geonet on slopes < 5%) above the secondary geomembrane liner, to collect and convey any liquid in the leak detection layer towards leak detection (bottom) sumps. The LCS and LDS components are completely separate drainage systems that are not connected to each other.

Thus, on the cell floor areas, the separate LCS and LDS drainage layers will each convey collected liquid towards collection corridors spaced throughout the cell (see layout plan on Drawing #4 and details on Drawing #12 in Appendix A). The LCS and LDS collection corridors each have a perforated collection pipe surrounded by coarse aggregate drainage material, surrounded by a geotextile filter. The sumps are filled with coarse aggregate drainage material, and have a perforated section of leachate riser pipe in the

sumps, in which a submersible pump will be installed to remove liquid from the sump. The riser pipe is solid wall on the sideslopes, and extends out of each sump area to the cell perimeter (i.e., top of perimeter levee on the northern cell perimeter).

The leachate collection rates and maximum leachate head on the primary liner system were estimated using the Hydrologic Evaluation of Landfill Performance (HELP) computer model, Version 3.07, developed by the EPA. HELP simulates hydrologic processes for a landfill by performing daily, sequential water balance analyses to estimate the liquid infiltrating into the landfill by performing daily, sequential water balance analyses to estimate the liquid infiltrating into the landfill and through the leachate collection layer. The hydrologic processes considered in the HELP model include precipitation, surface-water evaporation, runoff, infiltration, plant transpiration, soil water evaporation, soil water storage, vertical drainage (saturated and unsaturated), lateral drainage (saturated), vertical drainage (saturated) through soils and GCLs, and leakage through geomembranes. The leachate collection rate and maximum leachate head on the floor of the liner system were calculated for typical operational conditions. Drainage layers and pipes were sized accordingly. For all operational cases evaluated, the calculated head of leachate on the liner is less than the regulatory maximum of 30 cm (12 in.). Refer to Appendix E for a detailed description of the analyses, including approach, parameter selection, scenarios evaluated, and results.

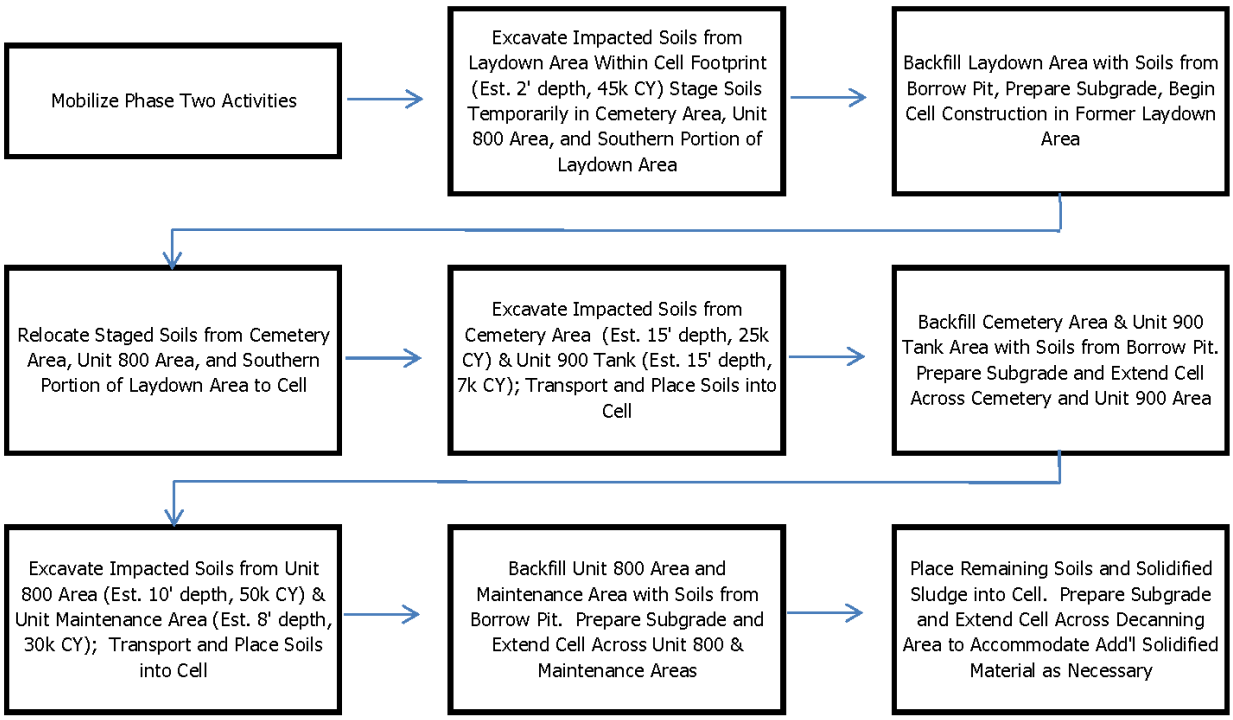
For the various collection and riser pipes that will be buried within the RCRA cell, the following four potential strength failure mechanisms for plastic pipes were evaluated: (i) wall crushing; (ii) wall buckling; (iii) excessive ring deflection; and (iv) excessive bending strain. These mechanisms were evaluated using methods presented in the technical literature for flexible plastic pipes. Stresses applied to the pipes are estimated for the final closed condition (i.e., the maximum load). The analyses indicate that the various specified HDPE pipe components of the LCS and LDS have sufficient strength to withstand the expected loads.

2.2.7 Subtitle C Equivalent Cell Construction

The impacted soils located within the proposed cell footprint must first be excavated and backfilled to accommodate cell subgrade construction. As a result, the construction of the cell subgrade and installation of the geosynthetics will be completed utilizing a phased approach that will include up to four separate phases as described previously. Although the boundaries of these phases may change, Drawing #4 in Appendix A illustrates the conceptual location. Initially, cell construction on an approximate eleven-acre area located in the former Laydown Area will be completed to accept solidified tank sludge waste and impacted soils currently located within the Tank 800, Tank 900, and Cemetery Areas. As these areas are remediated and backfilled, cell construction will progress toward the east, providing additional capacity for solidified sludge, debris, and soil excavated from future phases.

The conceptual plan to stage these excavations in a logical manner required for continuous cell construction is depicted in the following flow diagram:

Cell Construction Phasing Plan



Since the current design includes the placement of 1' of compacted clay directly beneath the GCL on the cell floor, additional excavation and backfill will be required in areas not being excavated during the impacted soil excavation step described in the flowchart above. In these areas, existing material will be excavated to the grades necessary, and then backfilled with clay which has previously been tested to demonstrate the material meets a minimum hydraulic conductivity of 1×10^{-7} cm/sec. Clay will also be placed in the final 1' layer of backfill placed in the impacted soil excavation areas to ensure the placement of 1' of compacted clay within the entire cell footprint beneath the geosynthetic system.

The floor of the cell will then be graded and compacted to afford a relatively flat, stable base for liner installation. The cell subgrade grading plan is illustrated on Drawing #4 in Appendix A which includes the construction of the southern berm to house the cell (the northern, eastern, and western berms will consist of the existing hurricane levee as depicted). Once the various phases of the cell floor are graded level and the side berms are installed, the prepared cell floor and sidewalls will be surveyed for as-built purposes and the cell liner system will be installed per the project drawings and specifications.

As shown on Drawing 10 in Appendix A, the cell liner system will consist of a geosynthetic clay liner (GCL), 80-mil High Density Polyethylene (HDPE) secondary geomembrane for leak detection, geonet, 80-mil HDPE primary geomembrane, and a geocomposite drainage layer. This system will include leachate collection which consists of a series of HDPE leachate collection pipes which are designed to transfer water to a series of leachate collection sumps which will house the pumps required for the removal of leachate from the cell during and after construction of the cell. The project drawings and

specifications included in Appendices A & B respectively provide the construction details and requirements for the installation of this system.

2.2.8 Subtitle C Equivalent Cover System Design

The RCRA cell final cover system is depicted in cross-sectional engineering details on Drawing #15 in Appendix A. As shown, final cover grades less than 5.8 percent are defined as "top" slope areas, and final cover grades equal to or greater than 5.8 percent are defined as "sideslope" areas. The final cover system will be composed of (from bottom to top, above the stabilized waste):

- double-sided geocomposite gas vent layer;
- geosynthetic clay liner (GCL);
- 40-mil linear low-density polyethylene (LLDPE) geomembrane (smooth on top slopes, textured on sideslopes);
- a final cover system drainage layer consisting of:
  - a single-sided geocomposite drainage layer (on top slope areas); or
  - a double-sided geocomposite drainage layer (on sideslopes);
- 1-ft thick protective cover soil layer;
- 6-in. thick vegetative layer (topsoil).

The vegetative layer will be seeded and mulched to establish grassy vegetation. There is a passive gas vent system designed for the RCRA cell. This is composed of the gas vent layer noted above, which will be a continuous blanket placed on top of the solidified waste; along with periodic passive gas vent pipes that will extend through the final cover system and above the ground surface, to ventilate the layer to the atmosphere. A gas vent detail is provided on Drawing #15.

The final cover components have been selected to: (i) provide long-term minimization of liquid migration into and through the closed RCRA cell; (ii) function with minimal maintenance; (iii) promote drainage and minimize erosion or abrasion of the cover; (iv) accommodate settling and subsidence so that the cover's integrity is maintained; and (v) have a barrier layer with a hydraulic conductivity less than or equal to the hydraulic conductivity of the bottom liner at the landfill.

2.2.9 Subtitle C Equivalent Cover System Construction

Once the cell is constructed and filled, the interior storm water channels will be contoured per the final grading plan to be submitted as part of the Phase Three RD/RA Work Plan. The soil cover system will then be installed in a series of parallel layers, as indicated generally on Figure 10 of the ROD and more specifically described on Drawing #15 in Appendix A to this Work Plan. The first layer of the cover system to be placed is the geocomposite gas collection layer containing a geonet with double-sided geotextile (i.e. on top and bottom). Next, a non-reinforced GCL will be placed across the flatter portions of the cover with a reinforced section placed around the exterior slopes. This will be followed by a smooth 40 mil LLDPE geomembrane on the flatter top portion, with a textured 40 mil HDPE used around the exterior slopes. The synthetic drainage layer will then be placed atop the 40 mil LLDPE, consisting of

a single sided geocomposite. At this point, the soil cover will be installed which consists of a 12-inch soil layer and a 6-inch vegetative cover layer. Permanent seeding will consist of a mix of local grass types which will provide the necessary vegetative cover.

It is anticipated that as operations progress from west to east, the cap and cover on the western portion of the cell will be installed. As waste placement and cell construction operations continue on the middle section of the cell and final grading is completed, the middle section will be tied into the previously completed section. As waste placement and cell construction operations continue on the eastern section of the cell, and final grading is completed, the eastern section will be tied into the previously completed section. Upon completion, all sections will be seamlessly integrated into a single RCRA cell. Specific conditions at the time of construction will ultimately determine the final details and location of the specific portions of the cell constructed at a particular time.

2.2.10 Storm Water Management

As Phase Two activities commence, storm water will continue to be managed in accordance with the approved Storm Water Management Plan included in the General RD/RA Work Plan. This plan has been modified to include Addendum #2 containing additional information regarding the strategy for the management of storm water on the site. The anticipated approach provides options to implement Best Management Practices (BMPs) for storm water management. It includes the operation of a water treatment system, the installation of an additional contact water storage facility, and other BMPs designed to minimize the amount of contact storm water generated during construction activities.

As required, all contact water will be sampled at the respective water surfaces and analyzed for the constituents listed in Table 2 and Table 3 of the Storm Water Management Plan. If the sample results are below the levels listed in Tables 2 and 3, the water will be pumped to a nearby lateral or drainage ditch for discharge to Campbell's Bayou or Swan Lake, until water levels are within approximately 1 foot of the waste contact or sludge surface. Once the water levels are within approximately 1 foot of the sludge, the water will be re-sampled. If at any point the sample results indicate the constituents are present above the levels shown in Tables 2 or 3, respectively, the water will be handled by either disposal via deep well injection or by treatment via an onsite water treatment plant. Water will only be discharged once sample results indicate the levels are below the limits listed in Tables 2 and 3 of the Storm Water Management Plan. Additional details regarding the water treatment plant design, testing frequencies, and the handling of contact storm water are included in the Addendum to the Storm Water Management Plan.

Non-contact storm water will be separated to the maximum extent practicable utilizing BMPs to allow this water to run off naturally across the Site and collect in the existing drainage ditches and laterals for conveyance to a discharge collection sump for discharge to Campbell's Bayou or Swan Lake. Prior to discharge, erosion and sedimentation controls will be in place to minimize sediment runoff into the storm water system.

3.0 SCHEDULE

The following project schedule provides the anticipated project start dates, sequence, inter-relationships, and durations for each activity of the Phase Two RA. The durations identified for each activity account for average weather delays and anticipated construction sequencing. This schedule is dependent upon approval of this work plan by USEPA after reasonable opportunity for review and comment by TCEQ. Mobilization to the site will occur in late March 2015 and work will continue uninterrupted until final completion of Phase Three which is anticipated to be completed by October 2016. The durations provided have been estimated based on a six days per week, 10-12 hours per day work schedule for remedial action activities. The general sequence of activities will be:

General Activities

- Mobilization
- Installation of storm water treatment plant & system startup
- Completion of groundwater extraction system & system startup
- Demolition of remaining tanks and concrete

Impacted Soil Removal

- Soil Excavation/Stockpiling/Placement
- Backfill Excavation Areas

RCRA C Cell Construction

- Subgrade preparation
- Geosynthetic installation
- Operations (cushion) layer placement
- Waste (soil, solidified sludge, & debris) placement

Sludge Solidification

- Tank/API Separator sludge solidification
- Sludge Pit/Oil Pit solidification
- Backfilling of pits upon completion of solidified sludge removal

RCRA C Cap Construction

- Final waste grading
- Geosynthetics installation
- Passive gas vent system installation
- Final cover soil placement
- Vegetative layer placement

Phase Three activities will take place immediately following the completion of the Phase Two work. Consequently, the development of the Phase Three Work Plan will be completed during the Phase Two

RA with ample review/approval time to allow Phase Three work to be completed unimpeded. The schedule shows the anticipated durations for the submittal, review, and approval of the Phase Three RD/RA Work Plan.

Malone Service Company Superfund Site
Phase Two RD/RA Schedule
05/22/15 Update

Activity ID	Description
Malone Service Company Superfund Site	
Phase Two Remedial Design	
2470	Submit Phase Two RD/RA Work Plan to EPA
2480	EPA Review Phase Two RD/RA Work Plan
2490	Response to EPA Comments
2540	EPA Approval of Phase Two RD/RA Workplan
Phase Two Remedial Action	
2410	Mobilize for Phase Two Activities
2420	Pre-Phase Two Activities
2430	Phase Two Remedial Action
Phase Three RD/RA	
2700	Submit Phase Three RD/RA Work Plan to EPA
2710	EPA Review Phase Three RD/RA Work Plan
2720	Response to EPA Comments
2730	EPA Approval of Phase Three RD/RA Work Plan
2740	Phase Three RA (Preliminary)

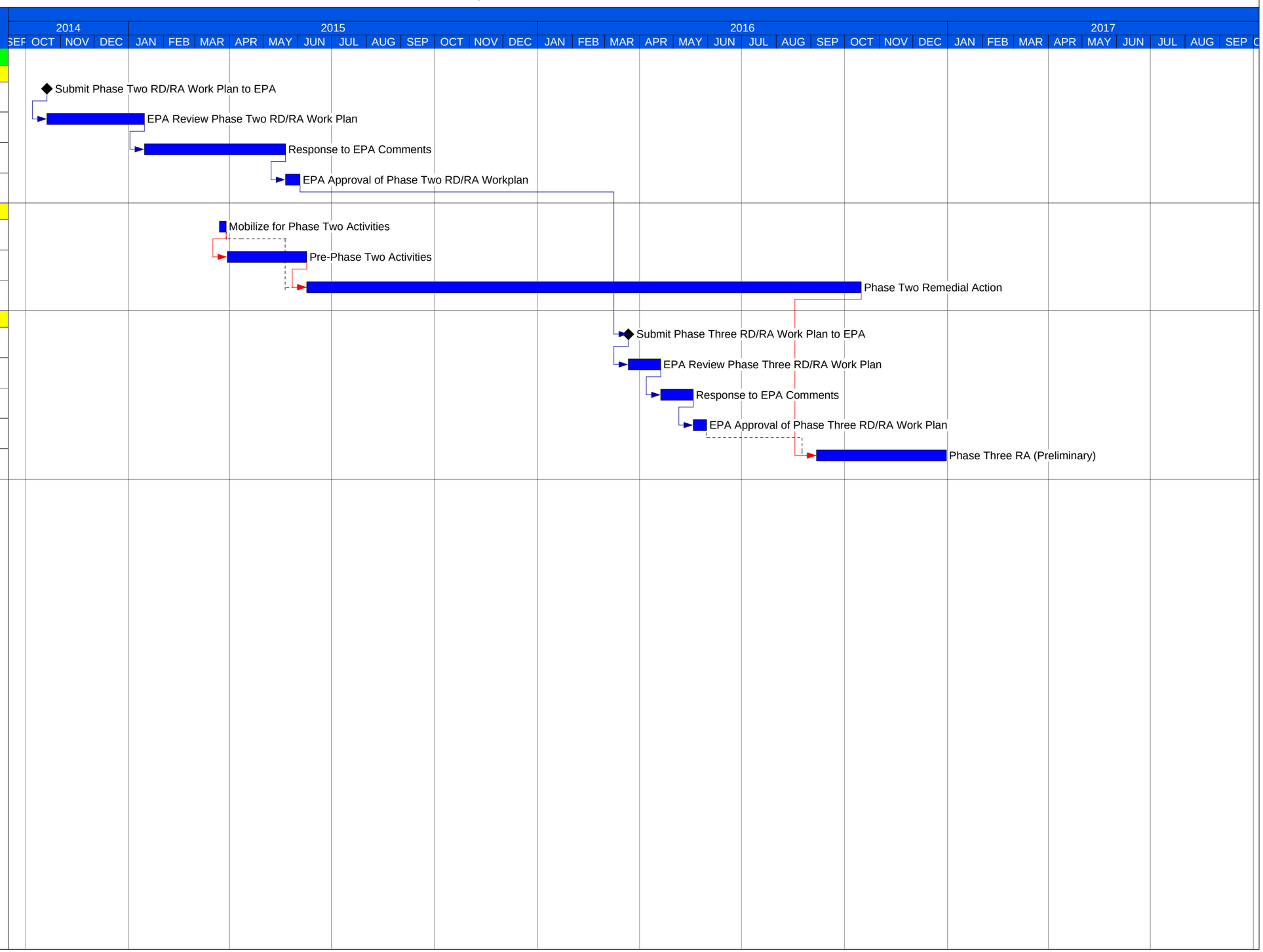
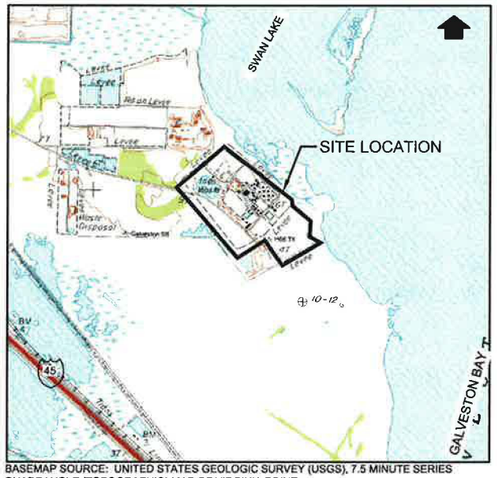


EXHIBIT 1
ENGINEERING DRAWINGS

MALONE SERVICE COMPANY
SUPERFUND SITE
RCRA SUBTITLE C CELL
TEXAS CITY, TEXAS
MAY 2015



BASEMAP SOURCE: UNITED STATES GEOLOGIC SURVEY (USGS), 7.5 MINUTE SERIES QUADRANGLE (TOPOGRAPHIC) MAP OF VIRGINIA POINT

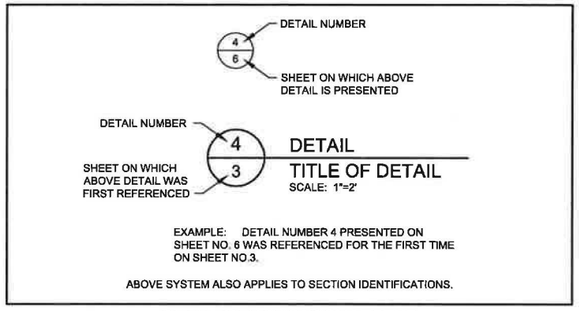
VICINITY MAP

0 2000'

APPROXIMATE SCALE

DRAWING LIST

DRAWING NUMBER	DRAWING TITLE	PREPARED BY	LATEST REVISION	DATE
1	TITLE SHEET	GEOSYNTEC	0	MAY 2015
2	GENERAL SITE PLAN	GEOSYNTEC	0	MAY 2015
3	EXISTING CELL AREA CONDITIONS PLAN	GEOSYNTEC	0	MAY 2015
4	TOP OF COMPACTED CLAY LINER GRADING PLAN	GEOSYNTEC	0	MAY 2015
5	TOP OF WASTE GRADING PLAN	GEOSYNTEC	0	MAY 2015
6	TOP OF FINAL COVER GRADING PLAN	GEOSYNTEC	0	MAY 2015
7	CELL CROSS SECTION A	GEOSYNTEC	0	MAY 2015
8	CELL CROSS SECTION B	GEOSYNTEC	0	MAY 2015
9	CELL CROSS SECTION C	GEOSYNTEC	0	MAY 2015
10	LINER SYSTEM DETAILS I	GEOSYNTEC	0	MAY 2015
11	LINER SYSTEM DETAILS II	GEOSYNTEC	0	MAY 2015
12	LEACHATE COLLECTION AND LEAK DETECTION SYSTEM DETAILS I	GEOSYNTEC	0	MAY 2015
13	LEACHATE COLLECTION AND LEAK DETECTION SYSTEM DETAILS II	GEOSYNTEC	0	MAY 2015
14	LEACHATE COLLECTION AND LEAK DETECTION SYSTEM DETAILS III	GEOSYNTEC	0	MAY 2015
15	FINAL COVER DETAILS I	GEOSYNTEC	0	MAY 2015
16	FINAL COVER DETAILS II	GEOSYNTEC	0	MAY 2015
17	SLUDGE REMEDIATION AREAS	ENTACT	0	MAY 2015
18	SLUDGE REMEDIATION AREAS CROSS SECTIONS	ENTACT	0	MAY 2015
19	SLUDGE PIT SOLIDIFICATION TREATMENT APPROACH	ENTACT	0	MAY 2015
20	OIL PIT SOLIDIFICATION TREATMENT APPROACH	ENTACT	0	MAY 2015
21	SOIL EXCAVATION AREAS	ENTACT	0	MAY 2015



EXAMPLE: DETAIL NUMBER 4 PRESENTED ON SHEET NO. 6 WAS REFERENCED FOR THE FIRST TIME ON SHEET NO.3.

ABOVE SYSTEM ALSO APPLIES TO SECTION IDENTIFICATIONS.

DETAIL IDENTIFICATION LEGEND

BASEMAP SOURCE: UNITED STATES GEOLOGIC SURVEY (USGS), 7.5 MINUTE SERIES QUADRANGLE (TOPOGRAPHIC) MAP OF VIRGINIA POINT

LOCATION MAP

0 5500'

APPROXIMATE SCALE

PREPARED FOR:

ENTACT
699 SOUTH FRIENDSWOOD DRIVE, SUITE 101
FRIENDSWOOD, TEXAS 77546
TELEPHONE:281-996-9892

PREPARED BY:

Geosyntec consultants
GEOSYNTEC CONSULTANTS, INC.
TEXAS ENG. FIRM REGISTRATION NUMBER 1182
8217 SHOAL CREEK BLVD., SUITE 200
AUSTIN, TEXAS 78757
TELEPHONE: 512.451.4003

ENGINEERING DESIGN DRAWING

REV	DATE	DESCRIPTION	DRN	APP
0	5/2015	ISSUED FINAL (USEPA ACCEPTANCE OF RESPONSES)	JJV	SMG
A	10/2014	ISSUED FINAL DRAFT FOR AGENCY REVIEW	JJV	SMG

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TITLE: TITLE SHEET

PROJECT: RCRA SUBTITLE C CELL

SITE: MALONE SERVICE COMPANY SUPERFUND SITE

5/4/2015

STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED PROFESSIONAL ENGINEER

DESIGN BY:	RG	DATE	OCTOBER 2014
DRAWN BY:	JJV / KH	PROJECT NO.:	TXL0299.02
CHECKED BY:	SMG	FILE	029902C01
REVIEWED BY:	SMG	DRAWING NO.:	1 OF 21
APPROVED BY:	SMG		

DRAWING: Austin P:\CADD\Projects\MM\Malone Superfund Site TX\CONSTRUCTION\RCRA CELL DESIGN (TXL0299.02)\DRAWINGS\029902C01.dwg PLOTTED: May 04, 2015 - 5:22pm

LEGEND

- EXISTING GROUND ELEVATION (NOTE 1)
- EXISTING FENCE
- EXISTING ROAD
- EXISTING TREELINE
- EXISTING WATERLINE
- N 13691000 / E 3275000 — STATE PLANE COORDINATES
- EXISTING BUILDING OR TANK
- PROPOSED RCRA SUBTITLE C CELL

NOTES:

1. THE EXISTING TOPOGRAPHIC BASE MAP WAS COMPILED FROM PHOTOGRAMMETRIC METHODS BASED ON AERIAL PHOTOGRAPHY PERFORMED ON 29 OCTOBER 2010 BY DAS.
2. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (FT. MSL) AS DEFINED BY LOCAL SITE DATUM. STATE PLANE COORDINATE GRID CORRESPONDS TO TEXAS STATE PLANE COORDINATE SYSTEM, TEXAS SOUTH CENTRAL ZONE (4204), NORTH AMERICAN DATUM-83 (NAD-83).

0 150' 300'
SCALE IN FEET

REV	DATE	DESCRIPTION	DRN	APP
0	5/2015	ISSUED FINAL (USEPA ACCEPTANCE OF RESPONSES)	JJV	SMG
A	10/2014	ISSUED FINAL DRAFT FOR AGENCY REVIEW	JJV	SMG

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TITLE: GENERAL SITE PLAN

PROJECT: RCRA SUBTITLE C CELL

SITE: MALONE SERVICE COMPANY SUPERFUND SITE

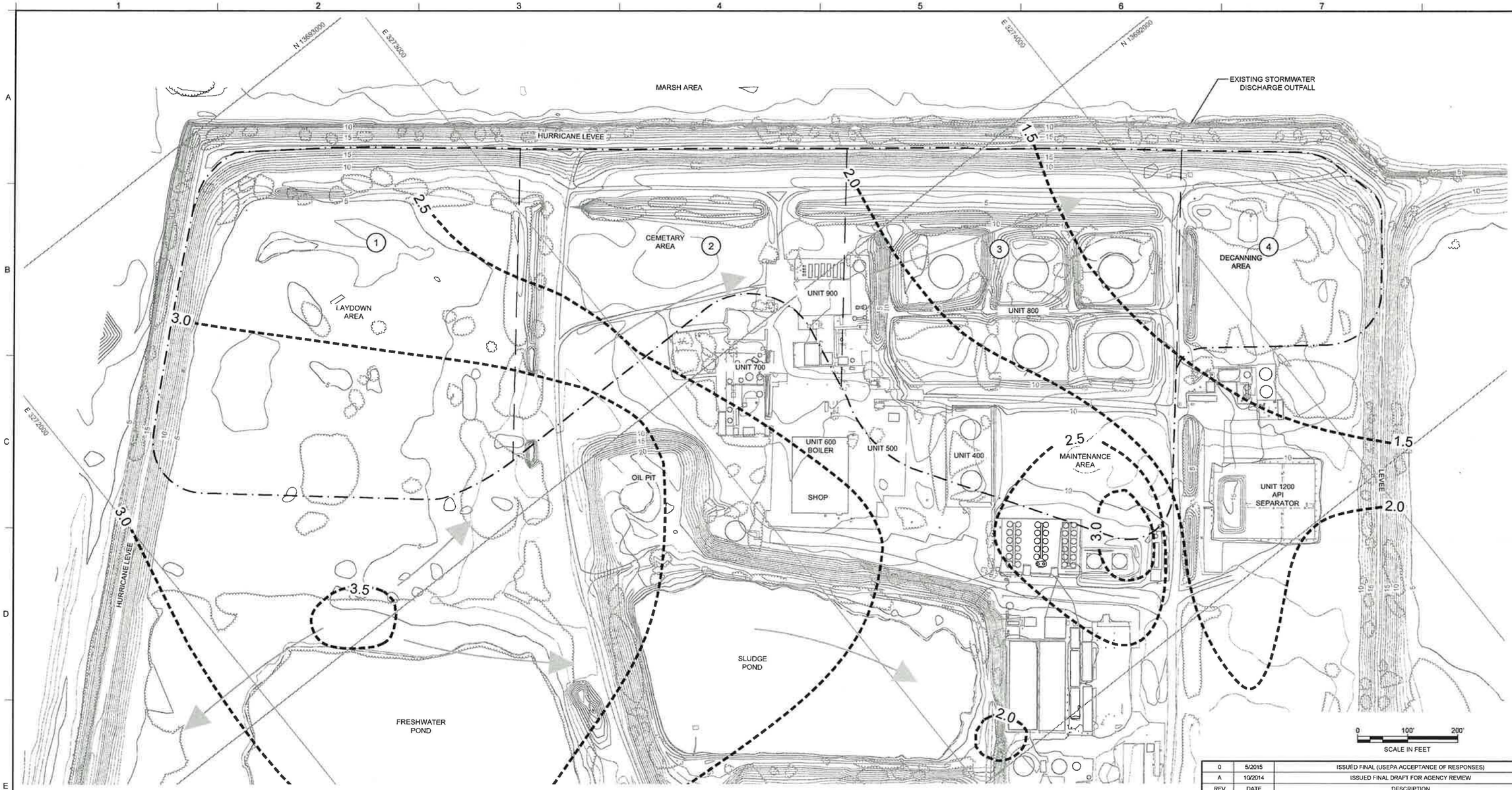
5/4/2015

STATE OF TEXAS — SCOTT M. GRAVES — 86557 — LICENSED PROFESSIONAL ENGINEER

DESIGN BY:	RG	DATE	OCTOBER 2014
DRAWN BY:	JJV / KH	PROJECT NO.	TXL0299.02
CHECKED BY	SMG	FILE	029902C02
REVIEWED BY:	SMG	DRAWING NO.:	2 OF 21
APPROVED BY	SMG		

ENGINEERING DESIGN DRAWING

DRAWING: Austin P:\CADD\Projects\Malone Superfund Site TX\CONSTRUCTION\RCRA CELL DESIGN (TXL0299.02)\DRAWINGS\029902C02.dwg PLOTTED: May 04, 2015 - 5:29pm



0 100' 200'

SCALE IN FEET

NOTES:

1. THE EXISTING TOPOGRAPHIC BASE MAP WAS COMPILED FROM PHOTOGRAMMETRIC METHODS BASED ON AERIAL PHOTOGRAPHY PERFORMED ON 29 OCTOBER 2010 BY DAS.
2. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (FT, MSL) AS DEFINED BY LOCAL SITE DATUM. STATE PLANE COORDINATE GRID CORRESPONDS TO TEXAS STATE PLANE COORDINATE SYSTEM, TEXAS SOUTH CENTRAL ZONE (4204), NORTH AMERICAN DATUM-83 (NAD-83) HARN.
3. GROUNDWATER ELEVATIONS AND FLOW DIRECTION TAKEN FROM AUTOCAD DRAWINGS PROVIDED BY ENTACT (e.g. FIGURE 14 SOIL EXCAVATION AREAS FOR MALONE SERVICE COMPANY SUPERFUND SITE).

LEGEND

- 650 — EXISTING GROUND ELEVATION (NOTE 1)
- EXISTING FENCE
- EXISTING ROAD
- EXISTING TREELINE
- EXISTING WATERLINE
- N 13874000 / E 2080000 — STATE PLANE COORDINATES
- EXISTING BUILDING
- PROPOSED RCRA SUBTITLE C CELL BOUNDARY
- 1 — PROPOSED PHASE BOUNDARY AND DESIGNATION
- 1.5 — GROUNDWATER ELEVATION (NOTE 3)
- GROUNDWATER FLOW DIRECTION (NOTE 3)

ENGINEERING DESIGN DRAWING

REV	DATE	DESCRIPTION	DRN	APP
0	5/2015	ISSUED FINAL (USEPA ACCEPTANCE OF RESPONSES)	JJV	SMG
A	10/2014	ISSUED FINAL DRAFT FOR AGENCY REVIEW	JJV	SMG

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PHONE: 512.451.4003

TITLE: EXISTING CELL AREA CONDITIONS PLAN

PROJECT: RCRA SUBTITLE C CELL

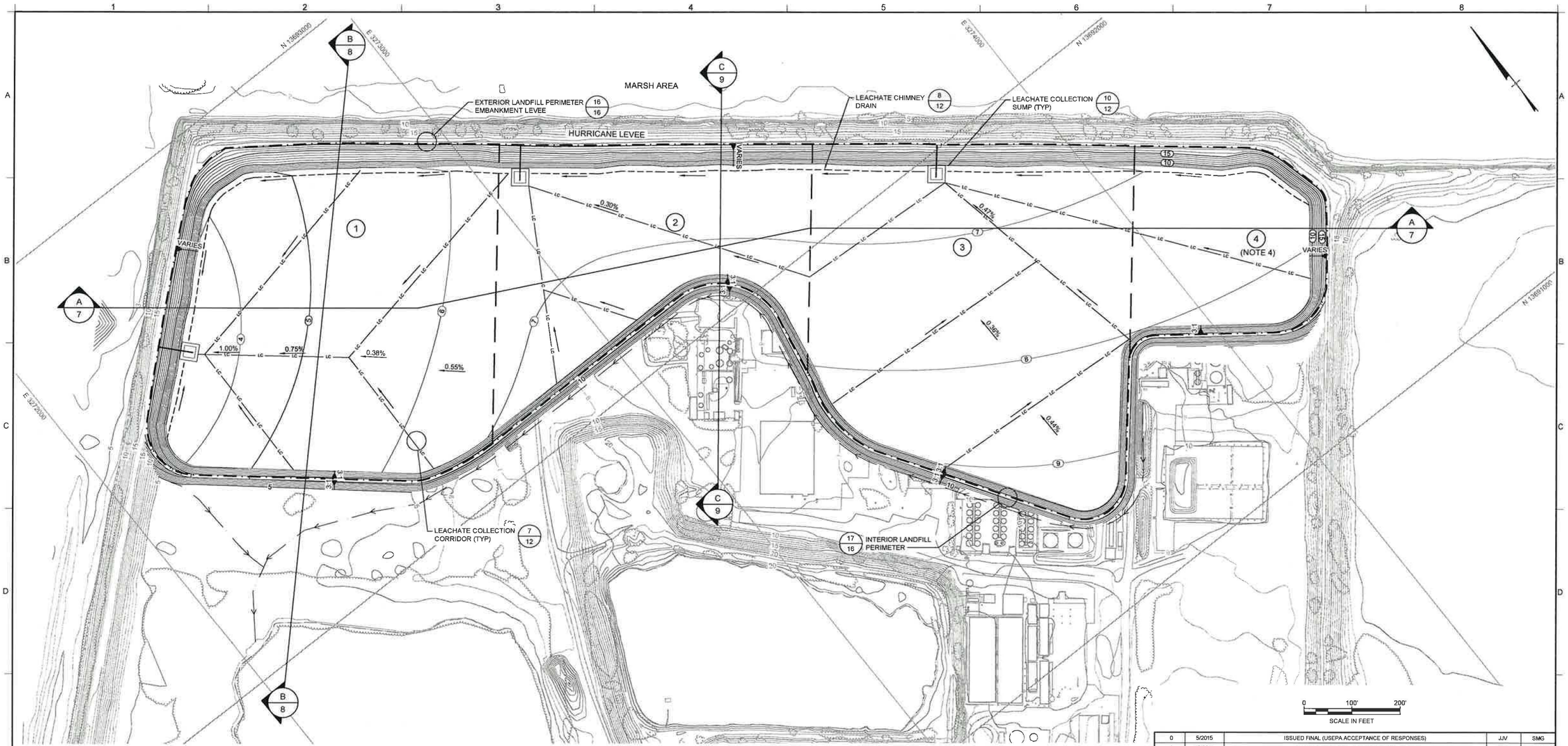
SITE: MALONE SERVICE COMPANY SUPERFUND SITE

5/4/2015

STATE OF TEXAS — SCOTT M. GRAVES — 86557 — LICENSED PROFESSIONAL ENGINEER

DESIGN BY:	RG	DATE:	OCTOBER 2014
DRAWN BY:	JJV / KH	PROJECT NO.:	TXL0299.02
CHECKED BY:	SMG	FILE:	029902C03
REVIEWED BY:	SMG	DRAWING NO.:	3 OF 21
APPROVED BY:	SMG		

DRAWING: Austin P:\CADD\Projects\MMalone Superfund Site TX\CONSTRUCTION\RCRA CELL DESIGN\ (TXL0299.02)\DRAWINGS\029902C03.dwg PLOTTED: May 04, 2015 - 5:36pm



LEGEND

- EXISTING GROUND ELEVATION CONTOUR (NOTE 1)
- EXISTING FENCE
- EXISTING ROAD
- EXISTING TREELINE
- EXISTING WATERLINE
- N 13691000 / E 3275000 — STATE PLANE COORDINATES
- EXISTING BUILDING / TANK
- POSSIBLE STORMWATER CHANNEL (OUTSIDE OF LIMITS OF DISTURBANCE)
- PROPOSED RCRA SUBTITLE C CELL BOUNDARY
- PROPOSED PHASE BOUNDARY AND DESIGNATION (NOTE 3)
- PROPOSED TOP OF COMPACTED CLAY LINER ELEVATION CONTOUR, FT
- PROPOSED FINISHED GRADE (OUTSIDE OF LINED AREA) ELEVATION CONTOUR (FT, MSL)
- LEACHATE COLLECTION CORRIDOR (WITH FLOW DIRECTION SHOWN)
- CHIMNEY DRAIN (WITH FLOW DIRECTION SHOWN)

NOTES:

1. THE EXISTING TOPOGRAPHIC BASE MAP WAS COMPILED FROM PHOTOGRAMMETRIC METHODS BASED ON AERIAL PHOTOGRAPHY PERFORMED ON 29 OCTOBER 2010 BY DAS.
2. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (FT, MSL) AS DEFINED BY LOCAL SITE DATUM. STATE PLANE COORDINATE GRID CORRESPONDS TO TEXAS STATE PLANE COORDINATE SYSTEM, TEXAS SOUTH CENTRAL ZONE (4204), NORTH AMERICAN DATUM-83 (NAD-83).
3. PHASE BOUNDARIES ARE APPROXIMATE AND MAY BE FIELD ADJUSTED BASED ON ACTUAL CONSTRUCTION TIMING (RATES OF WASTE PLACEMENT, ADJACENT SITE WORK, LINER INSTALLATION, ETC.)
4. PHASE 4 IS A CONTINGENCY AREA TO ALLOW DISPOSAL CAPACITY FOR ADDITIONAL WASTE VOLUMES, SHOULD IT BE NECESSARY. OTHERWISE, PHASE 4 WILL NOT BE BUILT.

ENGINEERING DESIGN DRAWING

REV	DATE	DESCRIPTION	DRN	APP
0	5/2015	ISSUED FINAL (USEPA ACCEPTANCE OF RESPONSES)	JJV	SMG
A	10/2014	ISSUED FINAL DRAFT FOR AGENCY REVIEW	JJV	SMG

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AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: TOP OF COMPACTED CLAY LINER GRADING PLAN

PROJECT: RCRA SUBTITLE C CELL

SITE: MALONE SERVICE COMPANY SUPERFUND SITE

5/4/2015

STATE OF TEXAS — SCOTT M. GRAVES — 86557 — LICENSED PROFESSIONAL ENGINEER

DESIGN BY:	RG	DATE:	OCTOBER 2014
DRAWN BY:	JJV / KH	PROJECT NO.	TXL0299.02
CHECKED BY:	SMG	FILE	029902C04
REVIEWED BY:	SMG	DRAWING NO.	4 OF 21
APPROVED BY:	SMG		

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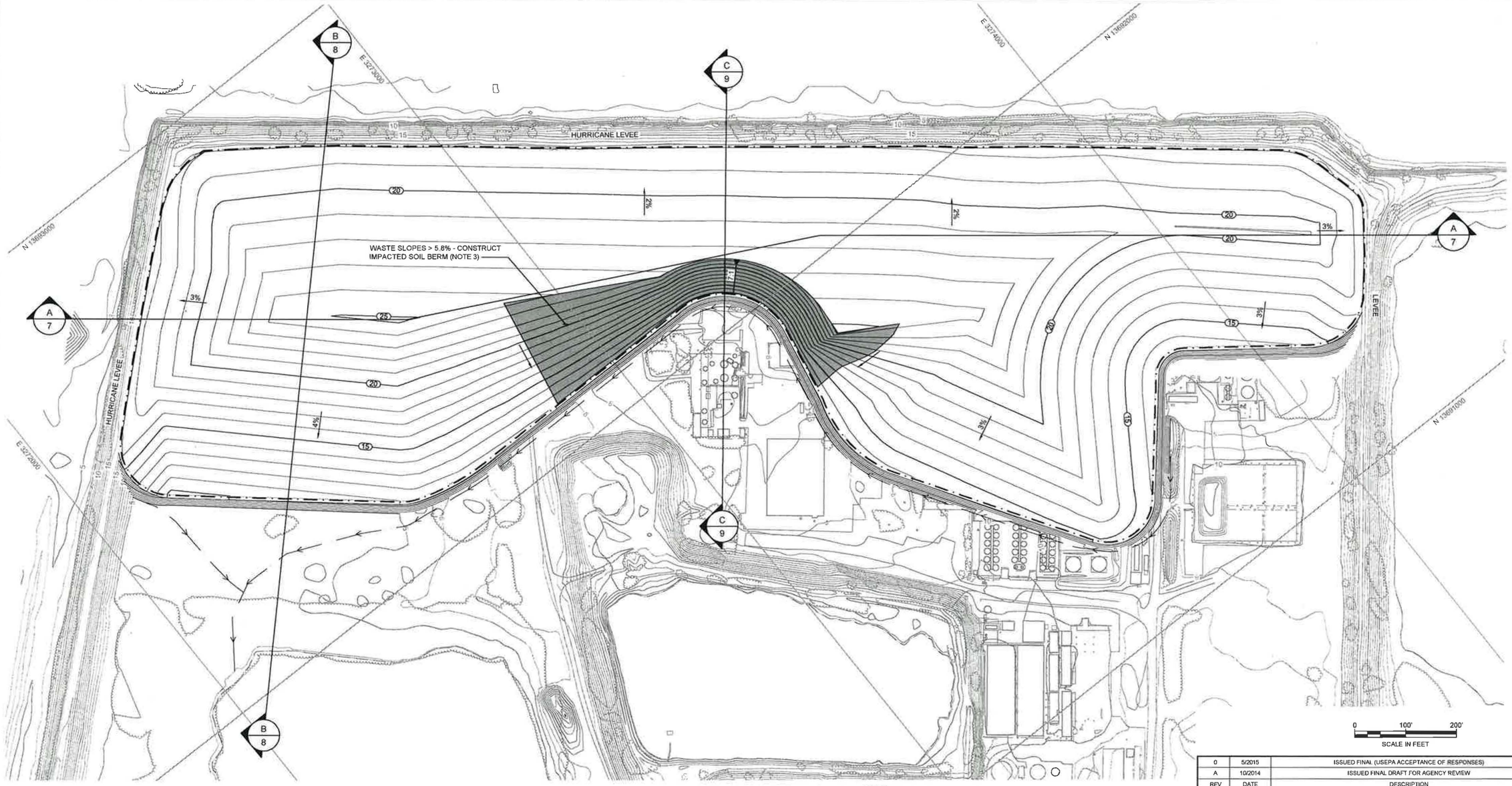

0 100' 200'
SCALE IN FEET

LEGEND

- 10 — EXISTING GROUND ELEVATION (NOTE 1)
- EXISTING FENCE
- EXISTING ROAD
- EXISTING TREELINE
- EXISTING WATERLINE
- N 13691000 / E 3275000 — STATE PLANE COORDINATES
- EXISTING BUILDING / TANK
- POSSIBLE STORMWATER CHANNEL (OUTSIDE OF LIMITS OF DISTURBANCE)
- PROPOSED RCRA SUBTITLE C CELL BOUNDARY
- (5) — PROPOSED TOP OF WASTE (BOTTOM OF FINAL COVER) ELEVATION (FT, MSL)
- 10 — PROPOSED FINISHED GRADE (OUTSIDE OF LINED AREA) ELEVATION CONTOUR (FT, MSL)

NOTES:

1. THE EXISTING TOPOGRAPHIC BASE MAP WAS COMPILED FROM PHOTOGRAMMETRIC METHODS BASED ON AERIAL PHOTOGRAPHY PERFORMED ON 29 OCTOBER 2010 BY DAS.
2. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (FT, MSL) AS DEFINED BY LOCAL SITE DATUM. STATE PLANE COORDINATE GRID CORRESPONDS TO TEXAS STATE PLANE COORDINATE SYSTEM, TEXAS SOUTH CENTRAL ZONE (4204), NORTH AMERICAN DATUM-83 (NAD-83).
3. SOLIDIFIED WASTE MAY BE PLACED ON FINAL WASTE SLOPES < 5.8%. IN AREAS ≥ 5.8%, THE FINAL WASTE SLOPES WILL BE CONSTRUCTED AS COMPACTED IMPACTED SOIL BERM WITHIN THE CELL. IMPACTED SOIL BERM WILL HAVE A 5' WIDE TOP AND 2:1 INTERNAL SIDESLOPES.

ENGINEERING DESIGN DRAWING

REV	DATE	DESCRIPTION	DRN	APP
0	5/2015	ISSUED FINAL (USEPA ACCEPTANCE OF RESPONSES)	JJV	SMG
A	10/2014	ISSUED FINAL DRAFT FOR AGENCY REVIEW	JJV	SMG

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8217 SHOAL CREEK BLVD., SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: TOP OF WASTE GRADING PLAN

PROJECT: RCRA SUBTITLE C CELL

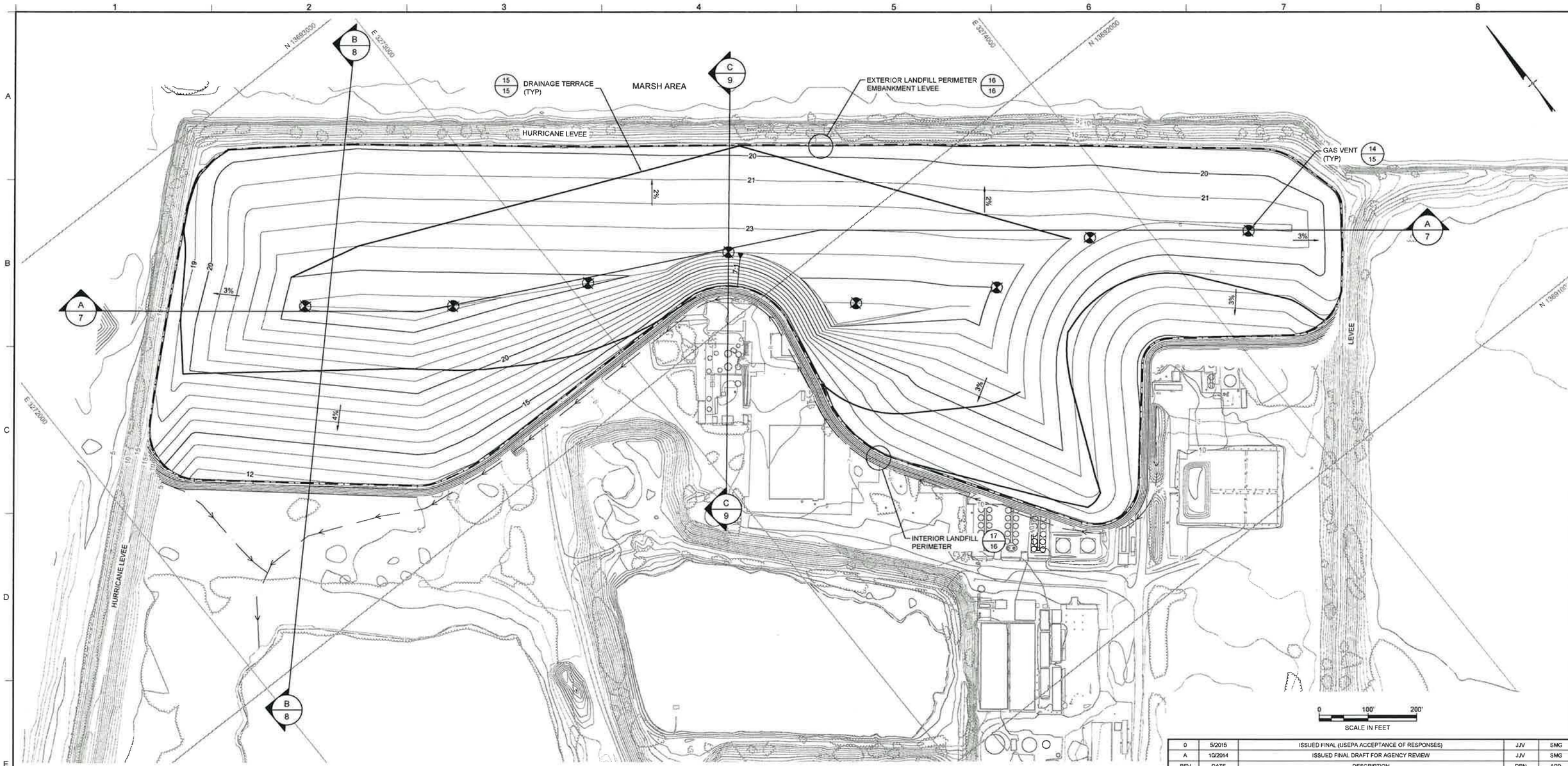
SITE: MALONE SERVICE COMPANY SUPERFUND SITE

5/4/2015

STATE OF TEXAS — SCOTT M. GRAVES — 86557 — LICENSED PROFESSIONAL ENGINEER

DESIGN BY:	RG	DATE	OCTOBER 2014
DRAWN BY:	JJV / KH	PROJECT NO.	TXL0299.02
CHECKED BY:	SMG	FILE	029902C05
REVIEWED BY:	SMG	DRAWING NO.	5 OF 21
APPROVED BY:	SMG		

DRAWING: Austin P:\CADD\Projects\Malone Superfund Site TX\CONSTRUCTION\RCRA CELL DESIGN (TXL0299.02)\DRAWINGS\029902C05.dwg PLOTTED: May 04, 2015 - 5:35pm



LEGEND

- EXISTING GROUND ELEVATION (NOTE 1)
- EXISTING FENCE
- EXISTING ROAD
- EXISTING TREELINE
- EXISTING WATERLINE
- N 13691000 / E 3275000 — STATE PLANE COORDINATES
- EXISTING BUILDING / TANK
- STORMWATER CHANNEL
- PROPOSED RCRA SUBTITLE C CELL BOUNDARY
- PROPOSED FINISHED GRADE ELEVATION CONTOUR (FT, MSL)
- GAS VENT
- DRAINAGE TERRACE (NOTE 4)

NOTES:

1. THE EXISTING TOPOGRAPHIC BASE MAP WAS COMPILED FROM PHOTOGRAMMETRIC METHODS BASED ON AERIAL PHOTOGRAPHY PERFORMED ON 29 OCTOBER 2010 BY DAS.
2. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (FT, MSL) AS DEFINED BY LOCAL SITE DATUM. STATE PLANE COORDINATE GRID CORRESPONDS TO TEXAS STATE PLANE COORDINATE SYSTEM, TEXAS SOUTH CENTRAL ZONE (4204), NORTH AMERICAN DATUM-83 (NAD-83).
3. GAS VENT LOCATIONS ARE APPROXIMATE AND MAY BE FIELD ADJUSTED SLIGHTLY.
4. DRAINAGE TERRACE LAYOUT IS CONCEPTUAL. THE PHASE 3 RD WORK PLAN WILL ADDRESS FINAL STORMWATER DRAINAGE DESIGN.

ENGINEERING DESIGN DRAWING

REV	DATE	DESCRIPTION	DRN	APP
0	5/2015	ISSUED FINAL (USEPA ACCEPTANCE OF RESPONSES)	JJV	SMG
A	10/2014	ISSUED FINAL DRAFT FOR AGENCY REVIEW	JJV	SMG

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AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: TOP OF FINAL COVER GRADING PLAN

PROJECT: RCRA SUBTITLE C CELL

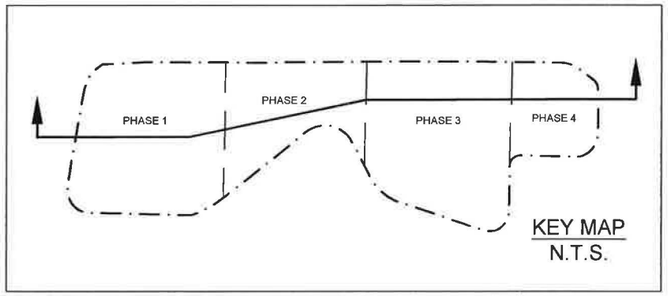
SITE: MALONE SERVICE COMPANY SUPERFUND SITE

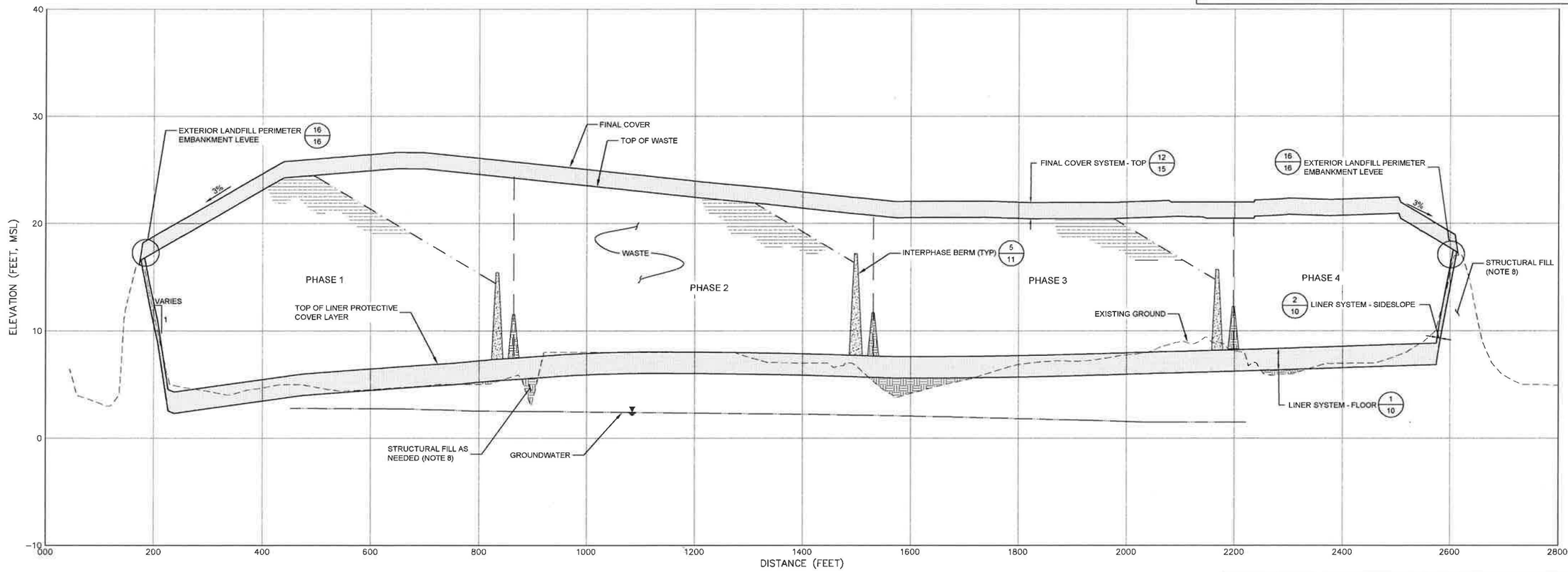
5/4/2015

STATE OF TEXAS — SCOTT M. GRAVES — 86557 — LICENSED PROFESSIONAL ENGINEER

DESIGN BY	RG	DATE	OCTOBER 2014
DRAWN BY	JJV / KH	PROJECT NO.	TXL0299.02
CHECKED BY	SMG	FILE	029902C06
REVIEWED BY	SMG	DRAWING NO.	6 OF 21
APPROVED BY	SMG		

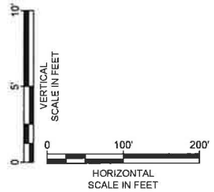
DRAWING: Austin P:\CADD\Projects\MMalone Superfund Site TX\CONSTRUCTION\RCRA CELL DESIGN (TXL0299.02)\DRAWINGS\029902C06.dwg PLOTTED: May 04, 2015 - 5:32pm





NOTES:

1. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (FT, MSL).
2. EXISTING GROUND SHOWN ON THIS DRAWING IS TAKEN FROM THE EXISTING CELL AREA CONDITIONS PLAN SHOWN ON DRAWING 3.
3. BOTTOM OF LINER SHOWN ON THIS DRAWING IS TAKEN FROM THE LINER SUBGRADE GRADING PLAN ON DRAWING 4.
4. TOP OF WASTE TAKEN FROM TOP OF WASTE GRADING PLAN ON DRAWING 5.
5. TOP OF FINAL COVER TAKEN FROM TOP OF FINAL COVER GRADING PLAN ON DRAWING 6.
6. GROUNDWATER TABLE TAKEN FROM EXISTING CELL AREA CONDITIONS PLAN ON DRAWING 3.
7. SLOPES, LINER SYSTEM THICKNESS, AND FINAL COVER SYSTEM THICKNESS MAY APPEAR DISTORTED ON THESE CROSS SECTIONS DUE TO THE EXAGGERATED VERTICAL SCALE AND THE SKEWED ANGLE AT WHICH THE SECTIONS WERE CUT COMPARED TO THE THREE-DIMENSIONAL SLOPE DIRECTIONS.
8. AREAS WHERE EXISTING GROUND ELEVATIONS ARE BELOW THE LINER SYSTEM SUBGRADE, OR BELOW FINISHED GRADE OF PERIMETER LANDFILL FEATURES (PERIMETER BERM) WILL BE FILLED WITH STRUCTURAL FILL, IN ACCORDANCE WITH SECTION 02300 (GENERAL EARTHWORK) OF THE TECHNICAL SPECIFICATIONS.



REV	DATE	DESCRIPTION	DRN	APP
0	5/2015	ISSUED FINAL (USEPA ACCEPTANCE OF RESPONSES)	JJV	SMG
A	10/2014	ISSUED FINAL DRAFT FOR AGENCY REVIEW	JJV	SMG

ENTACT
699 SOUTH FRIENDSWOOD DRIVE, SUITE 101
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Geosyntec consultants
GEOSYNTEC CONSULTANTS, INC.
TEXAS ENG. FIRM REGISTRATION NUMBER 1182
8217 SHOAL CREEK BLVD., SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: CELL CROSS SECTION A

PROJECT: RCRA SUBTITLE C CELL

SITE: MALONE SERVICE COMPANY SUPERFUND SITE

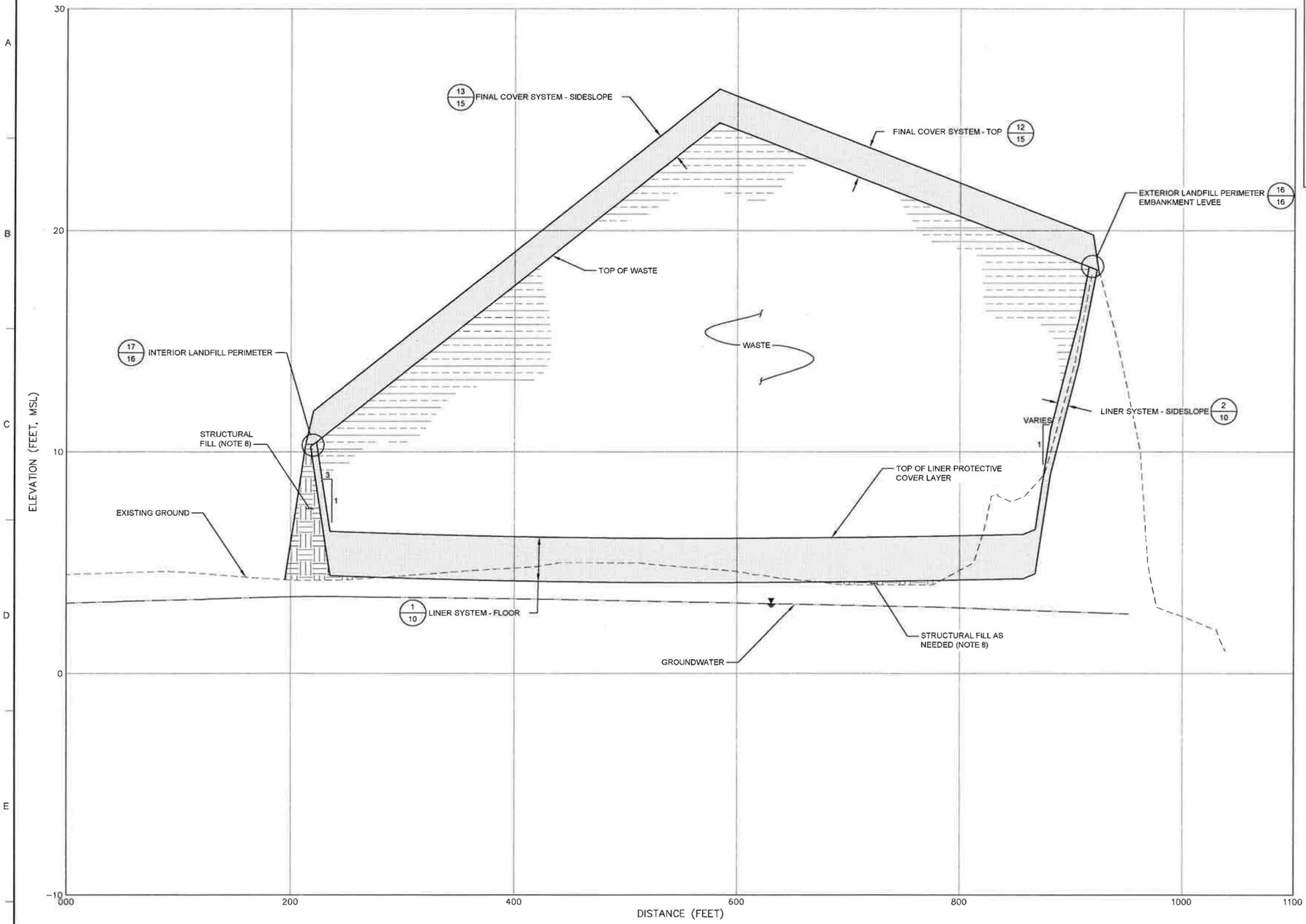
5/4/2015

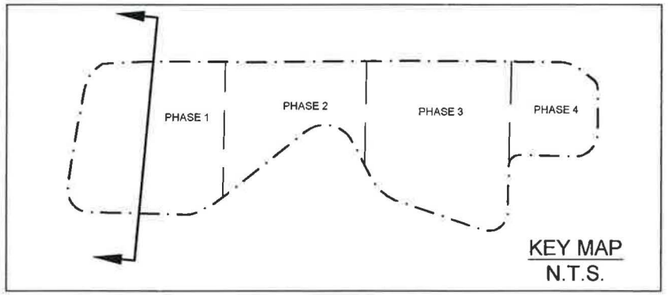
STATE OF TEXAS · SCOTT M. GRAVES · 86557 · LICENSED PROFESSIONAL ENGINEER

DESIGN BY:	RG	DATE:	OCTOBER 2014
DRAWN BY:	JJV / KH	PROJECT NO.:	TXL0299.02
CHECKED BY:	SMG	FILE:	029902C07
REVIEWED BY:	SMG	DRAWING NO.:	7 OF 21
APPROVED BY:	SMG		

ENGINEERING DESIGN DRAWING

DRAWING: Austin P:\CADD\Projects\MMalone Superfund Site TX\CONSTRUCTION\RCRA CELL DESIGN (TXL0299.02)\DRAWINGS\029902C07.dwg PLOTTED: May 04, 2015 - 5:38pm





NOTES:

1. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (FT, MSL).
2. EXISTING GROUND SHOWN ON THIS DRAWING IS TAKEN FROM THE EXISTING CELL AREA CONDITIONS PLAN SHOWN ON DRAWING 3.
3. BOTTOM OF LINER SHOWN ON THIS DRAWING IS TAKEN FROM THE LINER SUBGRADE GRADING PLAN ON DRAWING 4.
4. TOP OF WASTE TAKEN FROM TOP OF WASTE GRADING PLAN ON DRAWING 5.
5. TOP OF FINAL COVER TAKEN FROM TOP OF FINAL COVER GRADING PLAN ON DRAWING 6.
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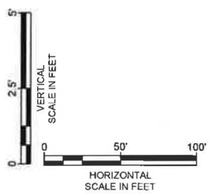

REV	DATE	DESCRIPTION	DRN	APP
0	5/2015	ISSUED FINAL (USEPA ACCEPTANCE OF RESPONSES)	JJV	SMG
A	10/2014	ISSUED FINAL DRAFT FOR AGENCY REVIEW	JJV	SMG

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AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: CELL CROSS SECTION B

PROJECT: RCRA SUBTITLE C CELL

SITE: MALONE SERVICE COMPANY SUPERFUND SITE

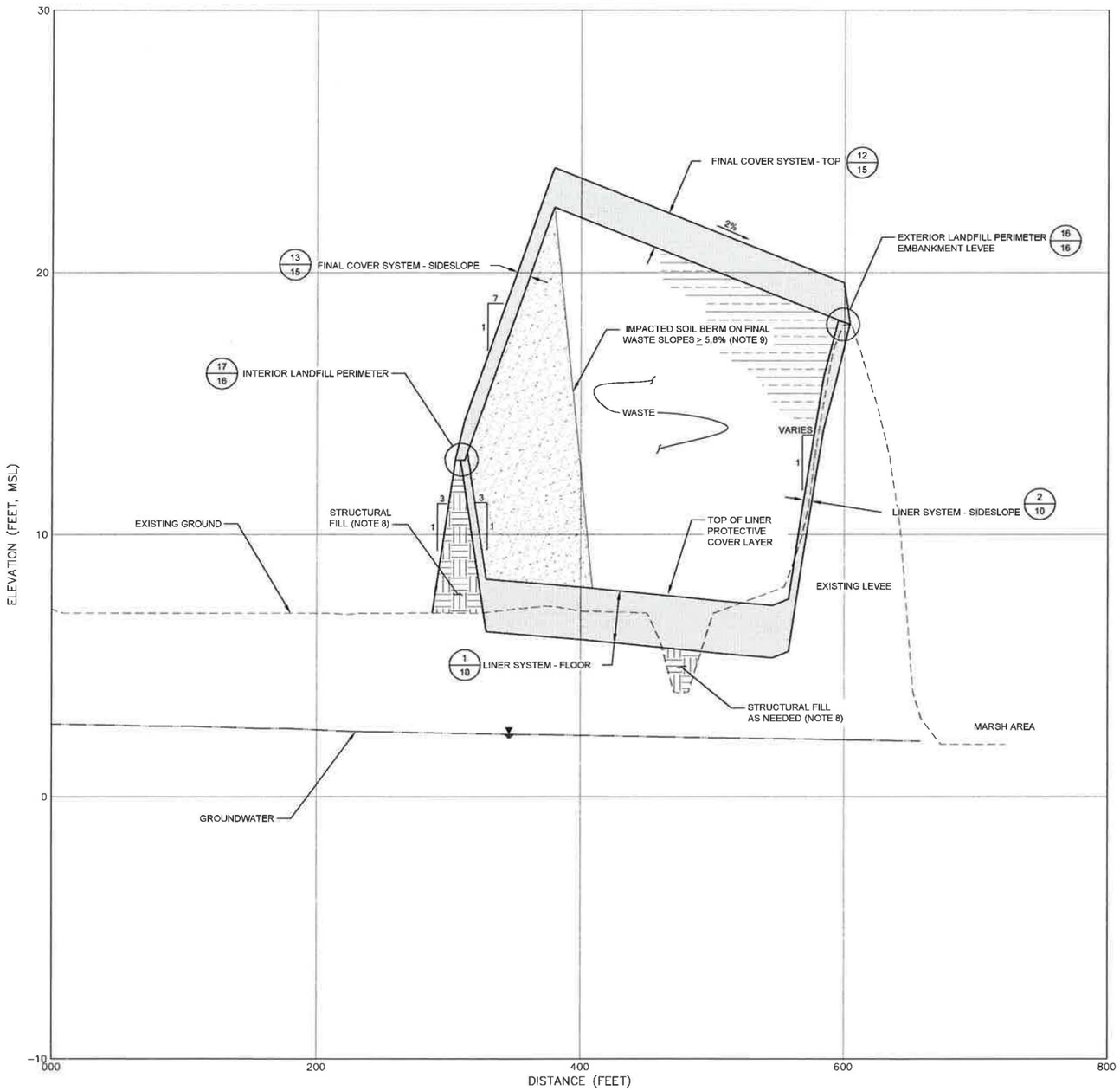
5/4/2015

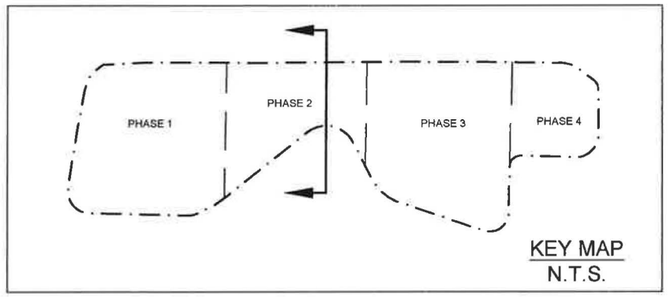
STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED PROFESSIONAL ENGINEER

DESIGN BY: RG		DATE: OCTOBER 2014	
DRAWN BY: JJV / KH		PROJECT NO.: TXL0299.02	
CHECKED BY: SMG		FILE: 029902C08	
REVIEWED BY: SMG		DRAWING NO.: 8 OF 21	
APPROVED BY: SMG			

ENGINEERING DESIGN DRAWING

DRAWING Austin P:\CAD\Projects\MM\Malone Superfund Site TX\CONSTRUCTION\RCRA CELL DESIGN (TXL0299.02)\DRAWINGS\029902C08.dwg PLOTTED May 04, 2015 - 5:42pm





NOTES:

1. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (FT, MSL).
2. EXISTING GROUND SHOWN ON THIS DRAWING IS TAKEN FROM THE EXISTING CELL AREA CONDITIONS PLAN SHOWN ON DRAWING 3.
3. BOTTOM OF LINER SHOWN ON THIS DRAWING IS TAKEN FROM THE LINER SUBGRADE GRADING PLAN ON DRAWING 4.
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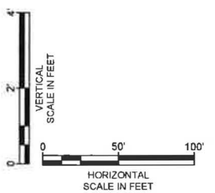
9. SOLIDIFIED WASTE MAY BE PLACED ON FINAL WASTE SLOPES < 5.8%. IN AREAS ≥ 5.8%, THE FINAL WASTE SLOPES WILL BE CONSTRUCTED AS COMPACTED IMPACTED SOIL BERM WITHIN THE CELL. IMPACTED SOIL BERM WILL HAVE A 5' WIDE TOP AND 2:1 INTERNAL SIDESLOPES.



REV	DATE	DESCRIPTION	DRN	APP
0	5/2015	ISSUED FINAL (USEPA ACCEPTANCE OF RESPONSES)	JJV	SMG
A	10/2014	ISSUED FINAL DRAFT FOR AGENCY REVIEW	JJV	SMG

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8217 SHOAL CREEK BLVD., SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: CELL CROSS SECTION C

PROJECT: RCRA SUBTITLE C CELL

SITE: MALONE SERVICE COMPANY SUPERFUND SITE

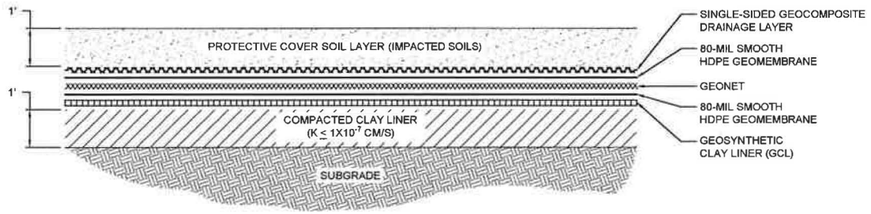
5/4/2015

STATE OF TEXAS
SCOTT M. GRAVES
85557
LICENSED
PROFESSIONAL ENGINEER

DESIGN BY:	RG	DATE	OCTOBER 2014
DRAWN BY:	JJV / KH	PROJECT NO.	TXL0299.02
CHECKED BY:	SMG	FILE	029902C09
REVIEWED BY:	SMG	DRAWING NO.	9 OF 21
APPROVED BY:	SMG		

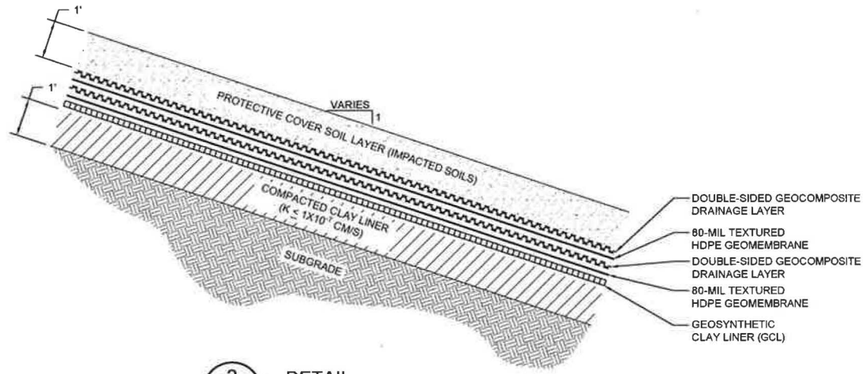
ENGINEERING DESIGN DRAWING

DRAWING Austin P:\CAD\Projects\Malone Superfund Site TX\CONSTRUCTION\RCRA CELL DESIGN (TXL0299.02)\DRAWINGS\029902C09.dwg PLOTTED May 04, 2015 - 5:39pm



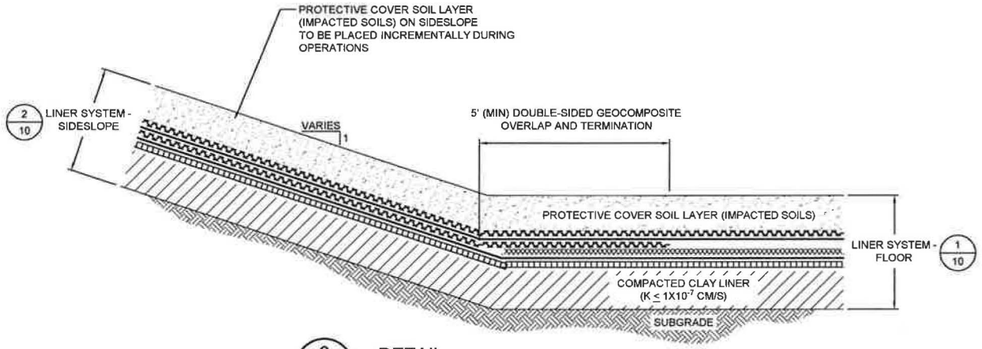
1/7 DETAIL
LINER SYSTEM - FLOOR
(SLOPES < 5%)

0 2' 4'
SCALE IN FEET



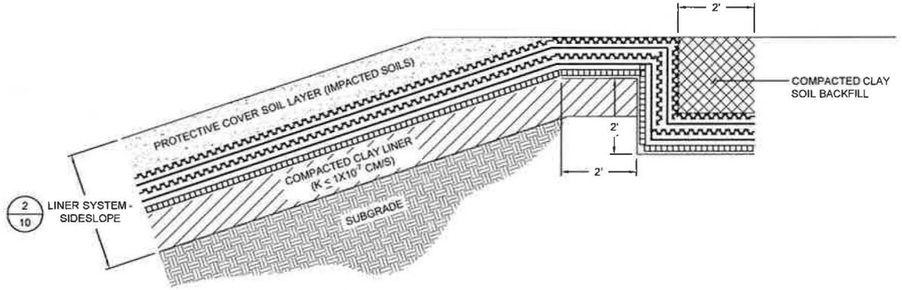
2/7 DETAIL
LINER SYSTEM - SIDESLOPE
(SLOPES ≥ 5%)

0 2' 4'
SCALE IN FEET



3/4 DETAIL
LINER SYSTEM TOE OF SLOPE
(NOTE: SEE DETAIL 8 FOR TOE OF SLOPE WITH CHIMNEY DRAIN)

0 2' 4'
SCALE IN FEET



4/14 DETAIL
LINER SYSTEM - ANCHOR TRENCH

0 2' 4'
SCALE IN FEET

NOTE:

1. DETAILS ARE SHOWN TO SCALE AS NOTED EXCEPT FOR GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. MATERIAL THICKNESSES ARE MINIMUMS. REQUIRED MATERIAL PROPERTIES ARE GIVEN IN THE SOIL AND LINER QUALITY CONTROL PLAN (SLQCP).

ENGINEERING DESIGN DRAWING

REV	DATE	DESCRIPTION	DRN	APP
0	5/2015	ISSUED FINAL (USEPA ACCEPTANCE OF RESPONSES)	JJV	SMG
A	10/2014	ISSUED FINAL DRAFT FOR AGENCY REVIEW	JJV	SMG

ENTACT
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TEXAS ENG. FIRM REGISTRATION NUMBER 1182
8217 SHOAL CREEK BLVD., SUITE 200
AUSTIN, TEXAS 78757
PHONE 512.451.4003

TITLE: LINER SYSTEM DETAILS I

PROJECT: RCRA SUBTITLE C CELL

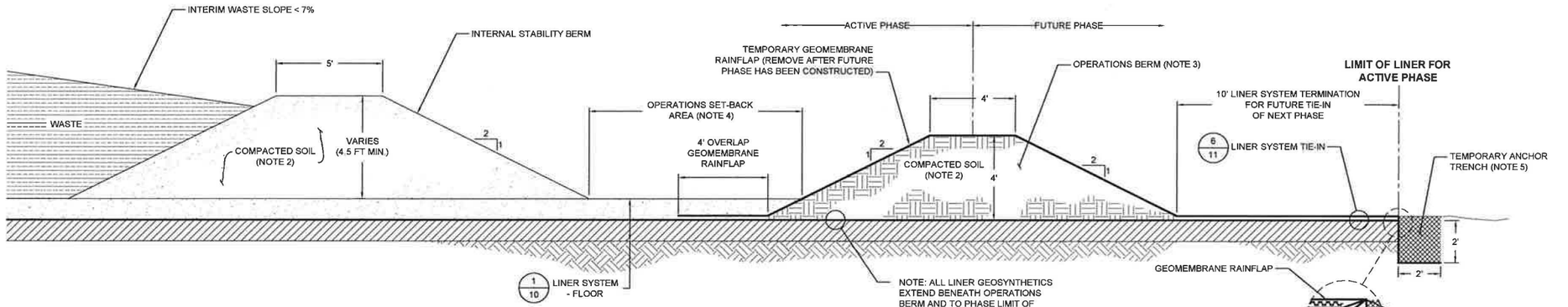
SITE: MALONE SERVICE COMPANY SUPERFUND SITE

5/4/2015

STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED
PROFESSIONAL ENGINEER

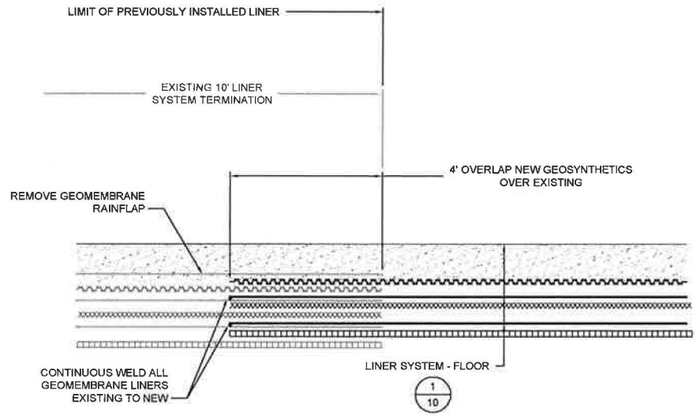
DESIGN BY: RG		DATE: OCTOBER 2014	
DRAWN BY: JJV / KH		PROJECT NO.: TXL0299.02	
CHECKED BY: SMG		FILE: 029902C12	
REVIEWED BY: SMG		DRAWING NO.: 10 OF 21	
APPROVED BY: SMG			

DRAWING: Austin P:\CAD\Projects\MMalone Superfund Site TX\CONSTRUCTION\RCRA CELL DESIGN (TXL0299.02)\DRAWING\029902C12.dwg PLOTTED: May 04, 2015 - 5:45pm



5/4 DETAIL
INTERPHASE BERM

0 3' 6'
SCALE IN FEET



6/11 DETAIL
LINER SYSTEM TIE-IN AT TEMPORARY TERMINATION

0 2' 4'
SCALE IN FEET

STEP 1) REMOVE RAIN FLAP INCLUDING TEMPORARY ANCHOR TRENCH

STEP 2) CUT LINER SYSTEM AT TEMPORARY WELD

STEP 3) PULL-BACK GEOSYNTHETICS TO ACHIEVE OVERLAPS

STEP 4) OVERLAP AND/OR TIE-IN GEOSYNTHETICS AS SHOWN

NOTES:

1. DETAILS ARE SHOWN TO SCALE AS NOTED EXCEPT FOR GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. MATERIAL THICKNESSES ARE MINIMUMS. REQUIRED MATERIAL PROPERTIES ARE GIVEN IN THE SOIL AND LINER QUALITY CONTROL PLAN (SLQCP).
2. COMPACTED SOIL FOR BERMS MAY BE IMPACTED SOIL OR STRUCTURAL FILL, AND IN EITHER CASE WILL BE PLACED IN ACCORDANCE WITH SECTION 02300 GENERAL EARTHWORK OF THE TECHNICAL SPECIFICATIONS.
3. OPERATIONS BERM AND "RAIN FLAP" CONCEPT IS FOR STORMWATER CONTROL TO PREVENT RUN-ON FROM ADJACENT AREAS FROM REACHING ACTIVE PHASE.
4. OPERATIONS SET-BACK AREA IS INTENDED AS A POSSIBLE HOLDING AREA FOR MANAGING OPERATIONS CONTACT WATER. IF USED, IT MUST PREVENT CONTACT WATER FROM PONDING ON LINER (E.G., USING TARPS)
5. TEMPORARY ANCHOR TRENCH IS FOR RAIN FLAP ANCHORAGE IN ORDER TO PROTECT LINER SYSTEM GEOSYNTHETICS UNTIL THE FUTURE TIE-IN IS MADE. ALTERNATE RAIN FLAP/TARP APPROACHES MAY BE USED WITHIN FUTURE PHASE AREA (E.G., CONTINUOUS TARP PLACED WITHIN FUTURE PHASE).

REV	DATE	DESCRIPTION	DRN	APP
0	5/2015	ISSUED FINAL (USEPA ACCEPTANCE OF RESPONSES)	JJV	SMG
A	10/2014	ISSUED FINAL DRAFT FOR AGENCY REVIEW	JJV	SMG

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699 SOUTH FRIENDSWOOD DRIVE, SUITE 101
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8217 SHOAL CREEK BLVD., SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: LINER SYSTEM DETAILS II

PROJECT: RCRA SUBTITLE C CELL

SITE: MALONE SERVICE COMPANY SUPERFUND SITE

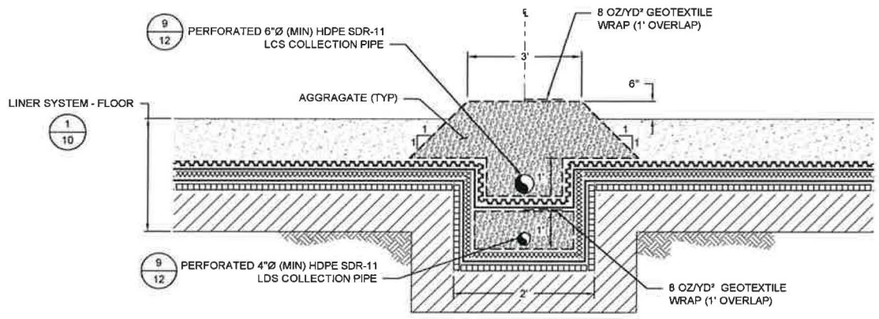
5/4/2015

STATE OF TEXAS · SCOTT M. GRAVES · 86557 · LICENSED PROFESSIONAL ENGINEER

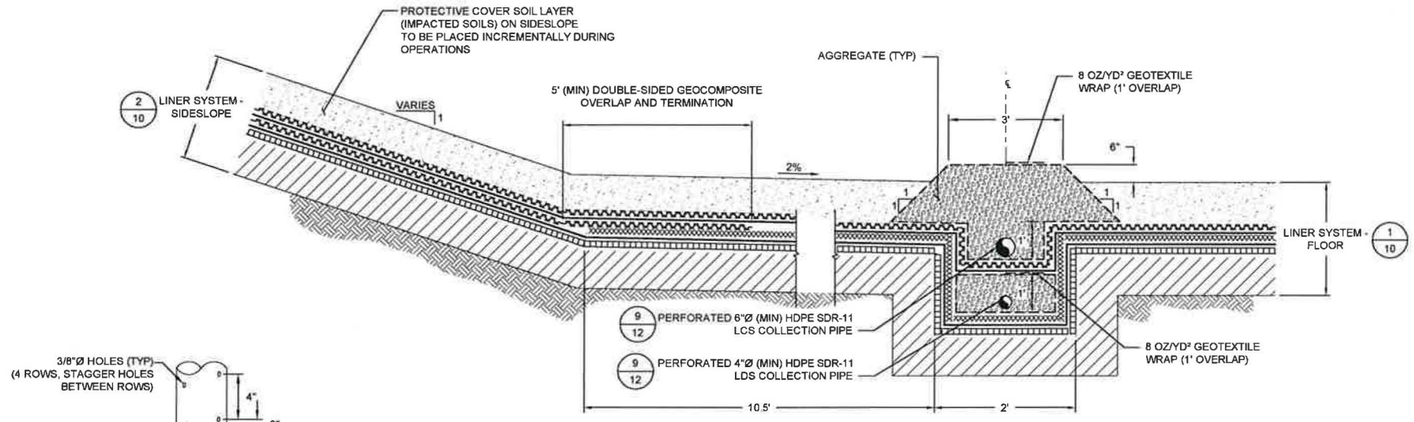
DESIGN BY:	RG	DATE:	OCTOBER 2014
DRAWN BY:	JJV / KH	PROJECT NO.:	TXL0299.02
CHECKED BY:	SMG	FILE:	029902C13
REVIEWED BY:	SMG	DRAWING NO.:	11 OF 21
APPROVED BY:	SMG		

ENGINEERING DESIGN DRAWING

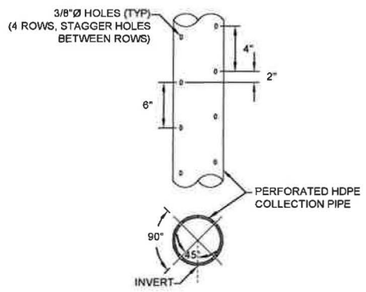
DRAWING: Austin P:\CADD\Projects\MMalone Superfund Site TX\CONSTRUCTION\RCRA CELL DESIGN (TXL0299.02)\DRAWINGS\029902C13.dwg PLOTTED: May 04, 2015 - 5:44pm



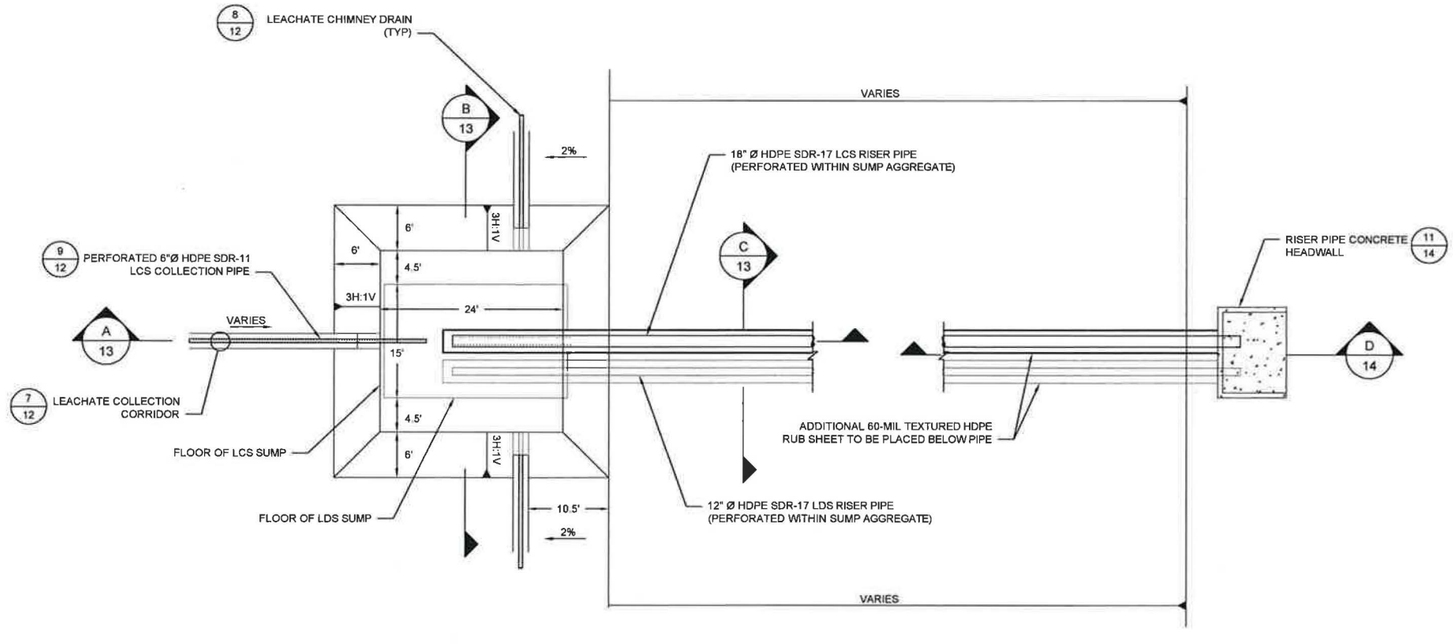
7/4 DETAIL
LEACHATE COLLECTION CORRIDOR (TYP)
SCALE: N.T.S.



8/4 DETAIL
LEACHATE CHIMNEY DRAIN
SCALE: N.T.S.



9/12 DETAIL
PIPE PERFORATIONS
SCALE: N.T.S.



10/4 DETAIL
LEACHATE COLLECTION SUMP
SCALE: N.T.S.

NOTE:

1. DETAILS ARE SHOWN TO SCALE AS NOTED EXCEPT FOR GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. MATERIAL THICKNESSES ARE MINIMUMS. REQUIRED MATERIAL PROPERTIES ARE GIVEN IN THE SOIL AND LINER QUALITY CONTROL PLAN (SLQCP).

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TEXAS ENG. FIRM REGISTRATION NUMBER 1182
8217 SHOAL CREEK BLVD., SUITE 200
AUSTIN, TEXAS 78757
PHONE 512.451.4003

TITLE: LEACHATE COLLECTION AND LEAK DETECTION SYSTEM DETAILS I

PROJECT: RCRA SUBTITLE C CELL

SITE: MALONE SERVICE COMPANY SUPERFUND SITE

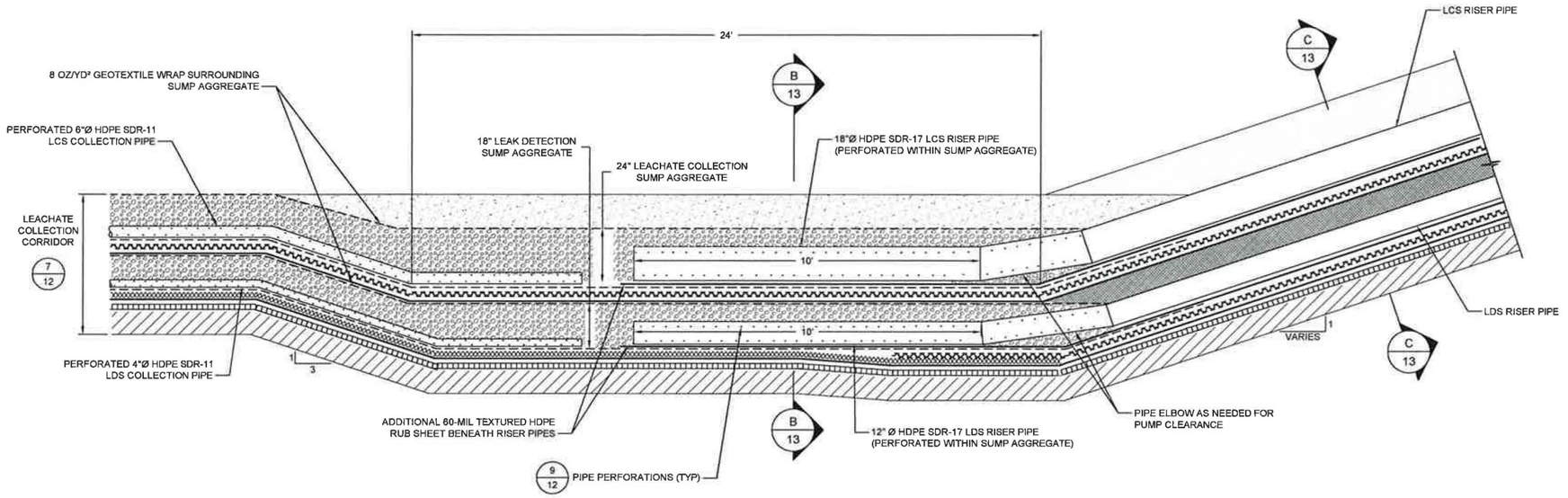
5/4/2015

STATE OF TEXAS · SCOTT M. GRAVES · 86557 · LICENSED PROFESSIONAL ENGINEER

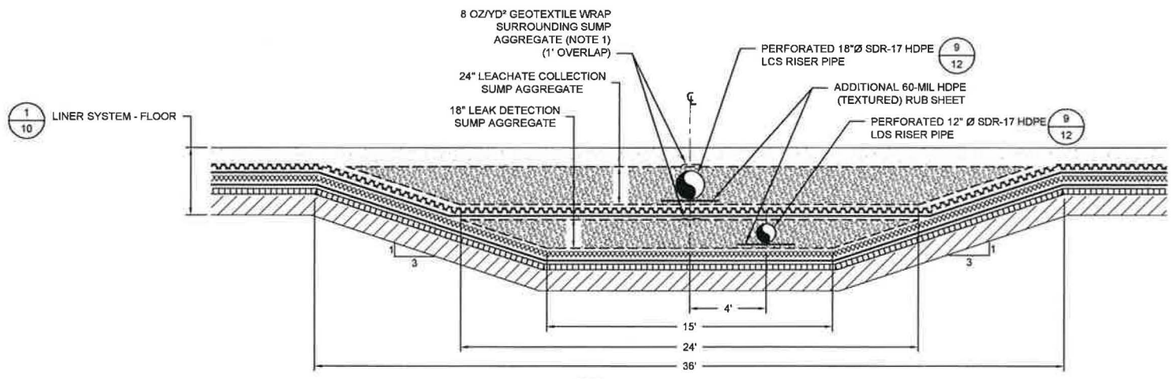
DESIGN BY: RG	DATE: OCTOBER 2014
DRAWN BY: JJV / KH	PROJECT NO.: TXL0299.02
CHECKED BY: SMG	FILE: 029902C14
REVIEWED BY: SMG	DRAWING NO.: 12 OF 21
APPROVED BY: SMG	

ENGINEERING DESIGN DRAWING

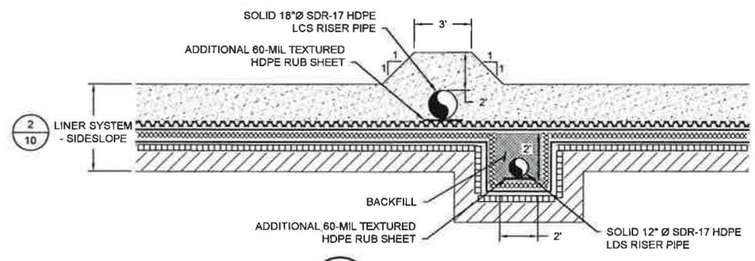
DRAWING Austin P:\CADD\Projects\Malone Superfund Site TX\CONSTRUCTION\RCRA CELL DESIGN (TXL0299.02)\DRAWINGS\029902C14.dwg PLOTTED May 04, 2015 - 5:23pm



A/12 SECTION
LEACHATE COLLECTION SUMP
SCALE: N.T.S.



B/12 SECTION
LEACHATE COLLECTION SUMP
SCALE: N.T.S.



C/12 SECTION
SIDESLOPE RISER PIPES
SCALE: N.T.S.

NOTE:

1. DETAILS ARE SHOWN TO SCALE AS NOTED EXCEPT FOR GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. MATERIAL THICKNESSES ARE MINIMUMS. REQUIRED MATERIAL PROPERTIES ARE GIVEN IN THE SOIL AND LINER QUALITY CONTROL PLAN (SLQCP).

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A	10/2014	ISSUED FINAL DRAFT FOR AGENCY REVIEW	JJV	SMG

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ENTACT
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FRIENDSWOOD, TEXAS 77546
PHONE: 281-996-9692 FAX 281-996-9888

Geosyntec consultants
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TEXAS ENG. FIRM REGISTRATION NUMBER 1182
8217 SHOAL CREEK BLVD., SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: LEACHATE COLLECTION AND LEAK DETECTION SYSTEM DETAILS II

PROJECT: RCRA SUBTITLE C CELL

SITE: MALONE SERVICE COMPANY SUPERFUND SITE

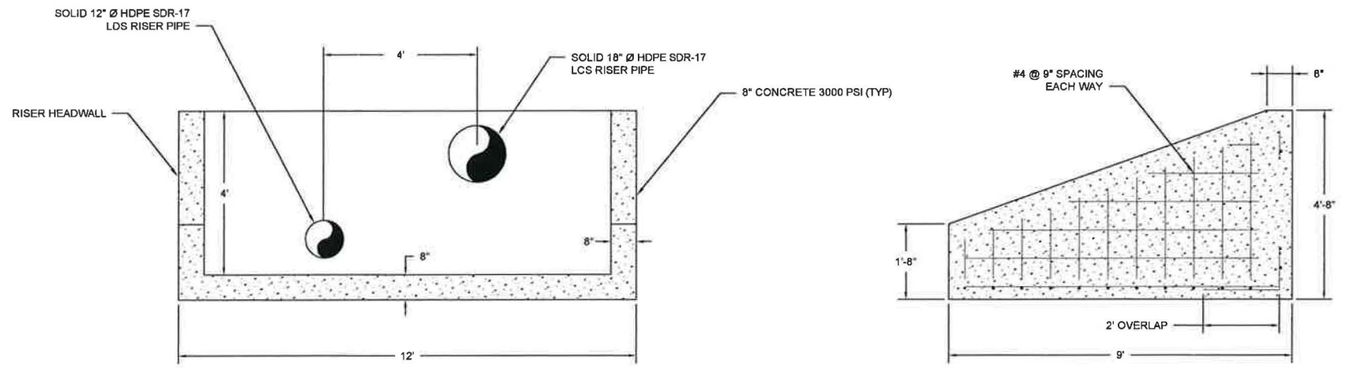
5/4/2015

STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED PROFESSIONAL ENGINEER

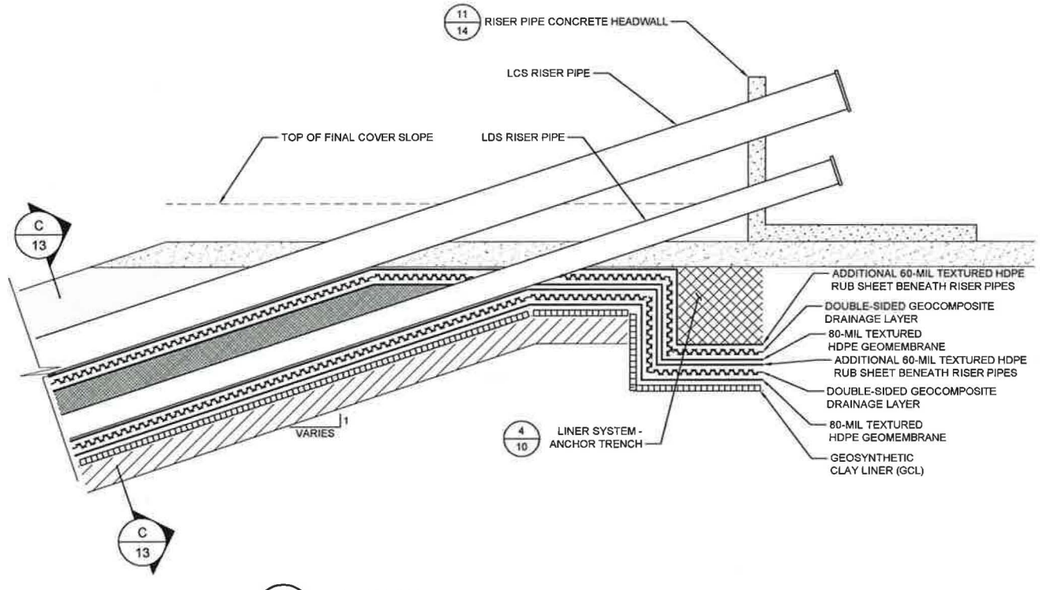
DESIGN BY:	RG	DATE	OCTOBER 2014
DRAWN BY:	JJV / KH	PROJECT NO.:	TXL0299.02
CHECKED BY:	SMG	FILE	029902C16
REVIEWED BY:	SMG	DRAWING NO.:	13 OF 21
APPROVED BY:	SMG		

ENGINEERING DESIGN DRAWING

DRAWING Austin P:\CADD\Projects\MMalone Superfund Site TX\CONSTRUCTION\RCRA CELL DESIGN (TXL0299.02)\DRAWINGS\029902C16.dwg PLOTTED: May 04, 2015 - 5:38pm



11/12 DETAIL
RISER PIPE CONCRETE HEADWALL
SCALE: N.T.S.



D/18 SECTION
LEACHATE RISER AT LANDFILL PERIMETER
SCALE: N.T.S.

REV	DATE	DESCRIPTION	DRN	APP
0	5/2015	ISSUED FINAL (USEPA ACCEPTANCE OF RESPONSES)	JJV	SMG
A	10/2014	ISSUED FINAL DRAFT FOR AGENCY REVIEW	JJV	SMG

ENTACT
ENTACT
699 SOUTH FRIENDSWOOD DRIVE, SUITE 101
FRIENDSWOOD, TEXAS 77546
PHONE 281-996-9692 FAX 281-996-9888

Geosyntec consultants
GEOSYNTEC CONSULTANTS, INC
TEXAS ENG. FIRM REGISTRATION NUMBER 1182
8217 SHOAL CREEK BLVD., SUITE 200
AUSTIN, TEXAS 78757
PHONE 512.451.4003

TITLE: LEACHATE COLLECTION AND LEAK DETECTION SYSTEM DETAILS III

PROJECT: RCRA SUBTITLE C CELL

SITE: MALONE SERVICE COMPANY SUPERFUND SITE

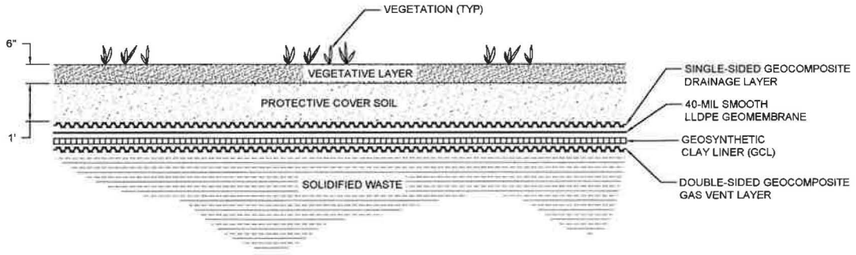
5/4/2015

STATE OF TEXAS · SCOTT M. GRAVES · 86557 · LICENSED PROFESSIONAL ENGINEER

DESIGN BY:	RG	DATE	OCTOBER 2014
DRAWN BY:	JJV / KH	PROJECT NO.	TXL0299.02
CHECKED BY:	SMG	FILE	029902C10
REVIEWED BY:	SMG	DRAWING NO.	14 OF 21
APPROVED BY:	SMG		

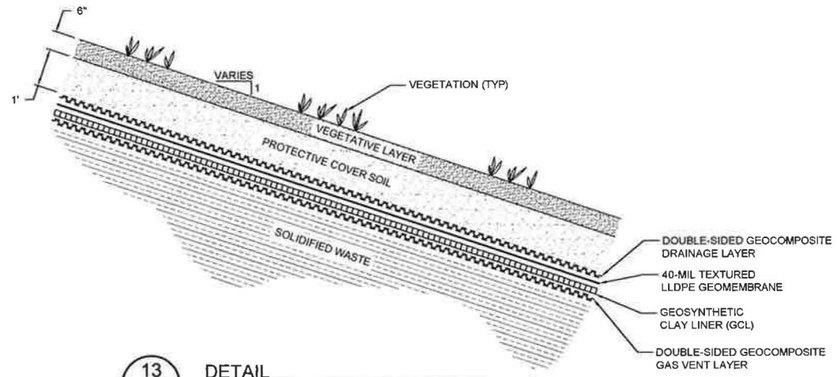
ENGINEERING DESIGN DRAWING

DRAWING: Austin P:\CADD\Projects\MMalone Superfund Site TX\CONSTRUCTION\RCRA CELL DESIGN (TXL0299.02)\DRAWINGS\029902C10.dwg PLOTTED: May 04, 2015 - 5:40pm



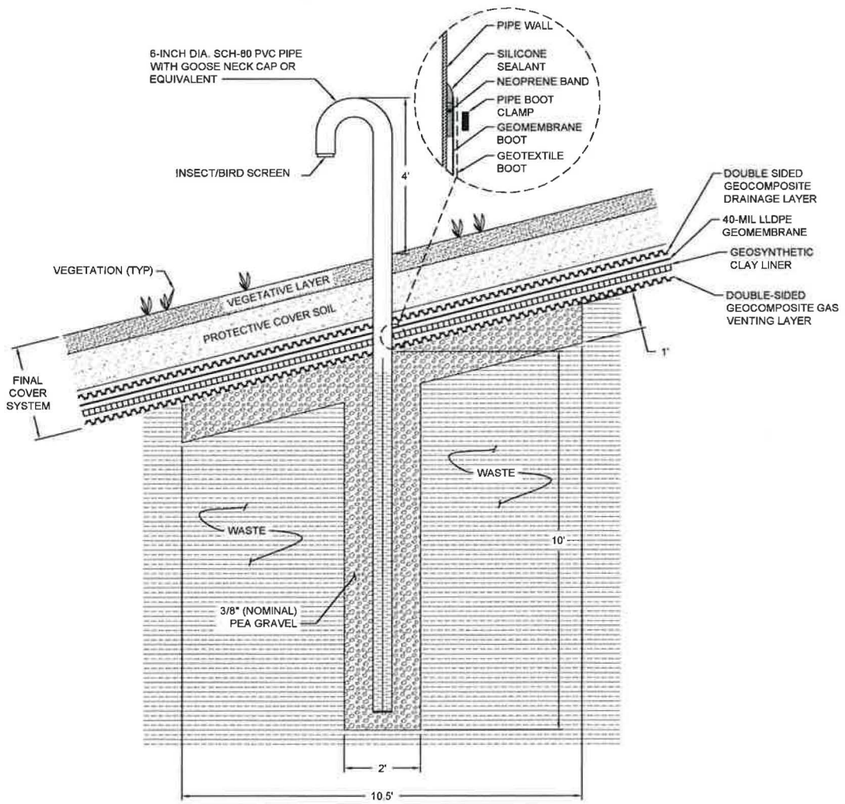
12/7 DETAIL
FINAL COVER SYSTEM - TOP
(SLOPES < 5.8%)

0 2' 4'
SCALE IN FEET



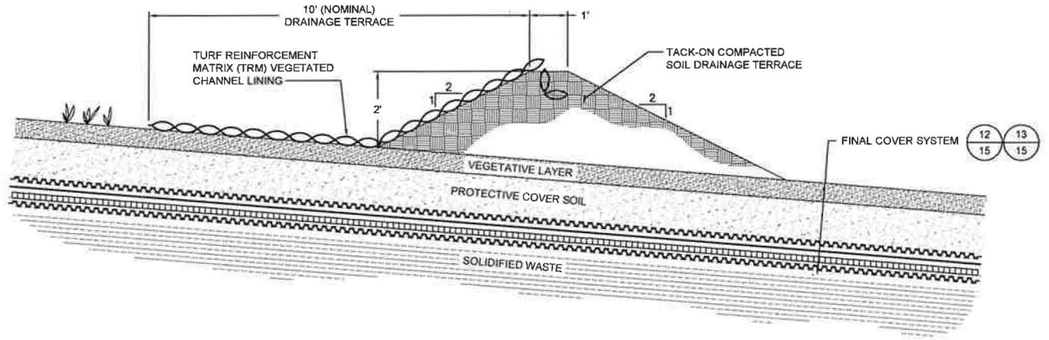
13/7 DETAIL
FINAL COVER SYSTEM - SIDESLOPE
(SLOPES ≥ 5.8%)

0 2' 4'
SCALE IN FEET



14/6 DETAIL
GAS VENT

0 2' 4'
SCALE IN FEET



13/6 DETAIL
DRAINAGE TERRACE (NOTE 2)

0 2' 4'
SCALE IN FEET

NOTES:

1. DETAILS ARE SHOWN TO SCALE AS NOTED EXCEPT FOR GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. MATERIAL THICKNESSES ARE MINIMUMS.
2. DRAINAGE TERRACE DETAIL IS CONCEPTUAL. THE PHASE 3 RD WORK PLAN WILL ADDRESS FINAL STORMWATER DRAINAGE DESING.

ENGINEERING DESIGN DRAWING

REV	DATE	DESCRIPTION	DRN	APP
0	5/2015	ISSUED FINAL (USEPA ACCEPTANCE OF RESPONSES)	JJV	SMG
A	10/2014	ISSUED FINAL DRAFT FOR AGENCY REVIEW	JJV	SMG

ENTACT
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699 SOUTH FRIENDSWOOD DRIVE, SUITE 101
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Geosyntec consultants
GEOSYNTEC CONSULTANTS, INC.
TEXAS ENG. FIRM REGISTRATION NUMBER 1182
8217 SHOAL CREEK BLVD., SUITE 200
AUSTIN, TEXAS 78757
PHONE 512.451.4003

TITLE: FINAL COVER DETAILS I

PROJECT: RCRA SUBTITLE C CELL

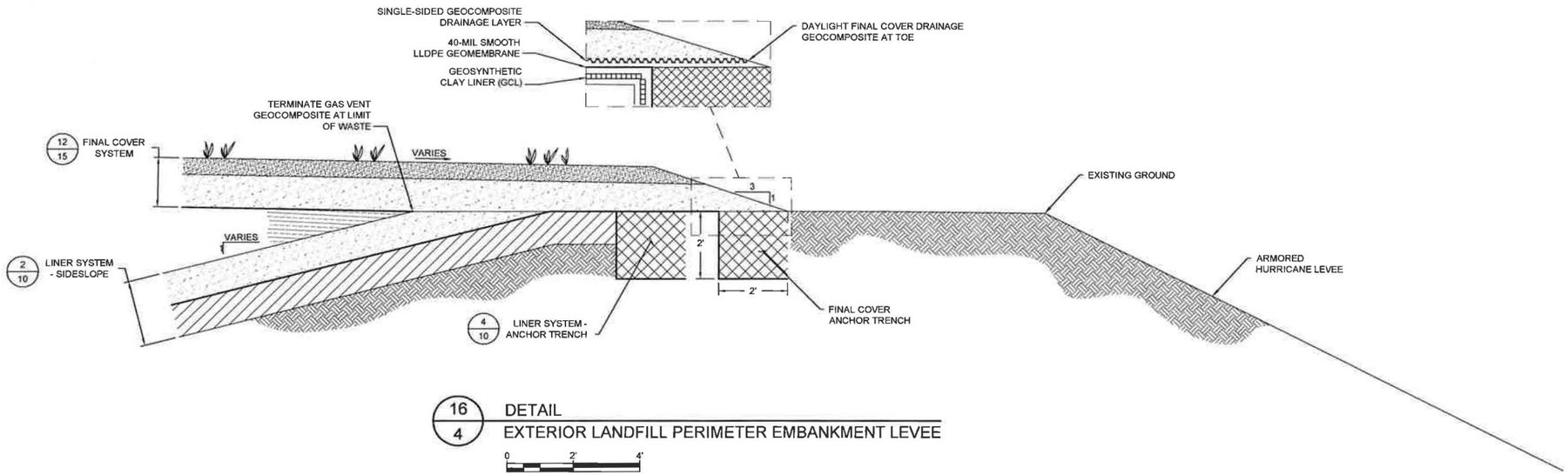
SITE: MALONE SERVICE COMPANY SUPERFUND SITE

5/4/2015

STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED
PROFESSIONAL ENGINEER

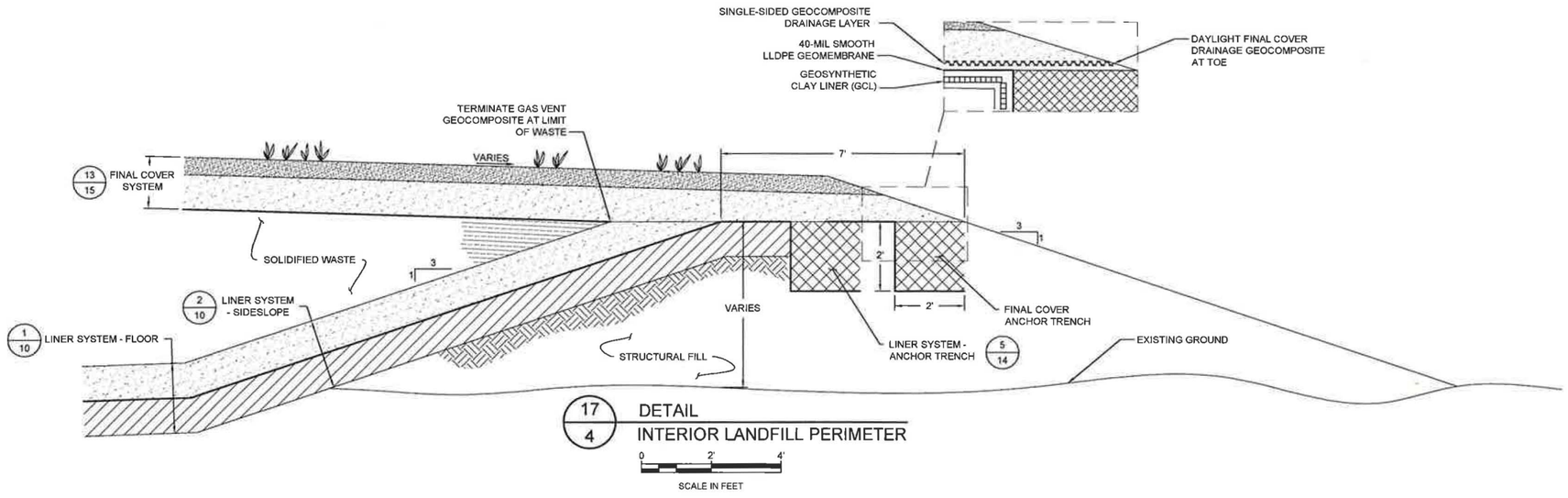
DESIGN BY	RG	DATE	OCTOBER 2014
DRAWN BY	JJV / KH	PROJECT NO.	TXL0299.02
CHECKED BY	SMG	FILE	029902C17
REVIEWED BY	SMG	DRAWING NO.	15 OF 21
APPROVED BY	SMG		

DRAWING: Austin P:\CADD\Projects\Malone Superfund Site TX\CONSTRUCTION\RCRA CELL DESIGN (TXL0299.02)\DRAWINGS\029902C17.dwg PLOTTED: May 04, 2015 - 5:40pm



16/4 DETAIL
EXTERIOR LANDFILL PERIMETER EMBANKMENT LEVEE

0 2' 4'
SCALE IN FEET



17/4 DETAIL
INTERIOR LANDFILL PERIMETER

0 2' 4'
SCALE IN FEET

NOTE:

1. DETAILS ARE SHOWN TO SCALE AS NOTED EXCEPT FOR GEOSYNTHETICS, WHICH ARE SHOWN AT AN EXAGGERATED SCALE FOR CLARITY. MATERIAL THICKNESSES ARE MINIMUMS.

REV	DATE	DESCRIPTION	DRN	APP
0	5/2015	ISSUED FINAL (USEPA ACCEPTANCE OF RESPONSES)	JJV	SMG
A	10/2014	ISSUED FINAL DRAFT FOR AGENCY REVIEW	JJV	SMG

ENTACT
ENTACT
699 SOUTH FRIENDSWOOD DRIVE, SUITE 101
FRIENDSWOOD, TEXAS 77546
PHONE: 281-996-9892 FAX: 281-996-9888

Geosyntec consultants
GEOSYNTEC CONSULTANTS, INC.
TEXAS ENG. FIRM REGISTRATION NUMBER 1182
8217 SHOAL CREEK BLVD., SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: FINAL COVER DETAILS II

PROJECT: RCRA SUBTITLE C CELL

SITE: MALONE SERVICE COMPANY SUPERFUND SITE

5/4/2015

STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED
PROFESSIONAL ENGINEER

DESIGN BY:	RG	DATE:	OCTOBER 2014
DRAWN BY:	JJV / KH	PROJECT NO.:	TXL0299.02
CHECKED BY:	SMG	FILE:	029902C18
REVIEWED BY:	SMG	DRAWING NO.:	16 OF 21
APPROVED BY:	SMG		

ENGINEERING DESIGN DRAWING

DRAWING: Austin P:\CAD\Projects\Malone Superfund Site TX\CONSTRUCTION\RCRA CELL DESIGN (TXL0299.02)\DRAWINGS\029902C18.dwg PLOTTED: May 04, 2015 - 5:28pm

Sludge Remediation Volume Report	
Source	Volume (cy)
Oil Pit	40,000
API Separator - Unit 100	5,000
API Separator - Unit 1200	5,000
Tanks	10,000
Sludge Pit	149,500
Total:	209,500

NOTES:

1. THIS DRAWING WAS CREATED BASED ON PHOTOGRAMMATIC SURVEY DATA COLLECTED BY DALLAS AERIAL SURVEYS, INC. ON 10/29/10 AS REQUESTED BY ENTACT.
2. THE INFORMATION PRESENTED HEREIN IS CONFIDENTIAL IN NATURE AND IS NOT TO BE REPRODUCED OR RE-USED WITHOUT THE EXPRESSED WRITTEN PERMISSION OF ENTACT.

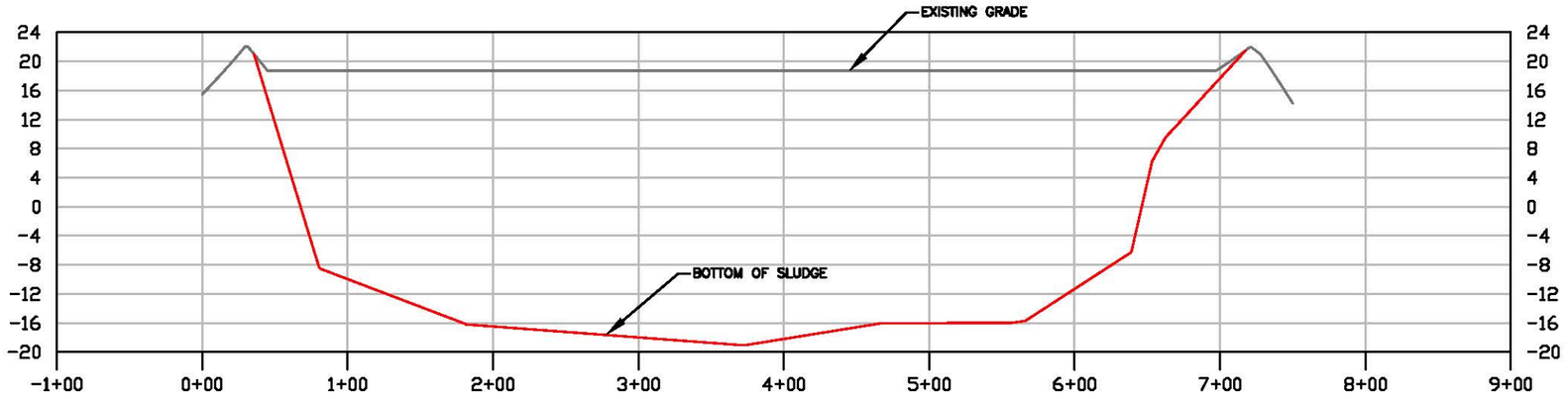
REV	DATE	BY	CHK'D	APR'VD	DESCRIPTION

ENTACT
699 South Friendswood Dr., Suite 101
Friendswood, Texas 77546
P: 281-996-9892

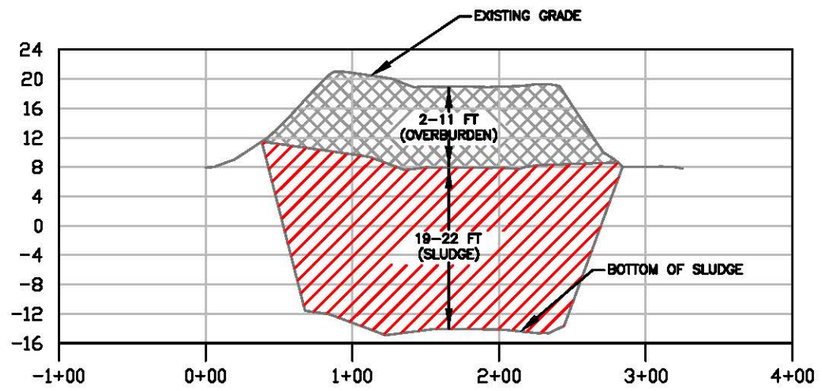
DRAWING NAME: DRAWING 17
SLUDGE REMEDIATION AREAS

PROJECT NAME & LOCATION: MALONE SERVICE COMPANY SUPERFUND SITE
TEXAS CITY, TEXAS

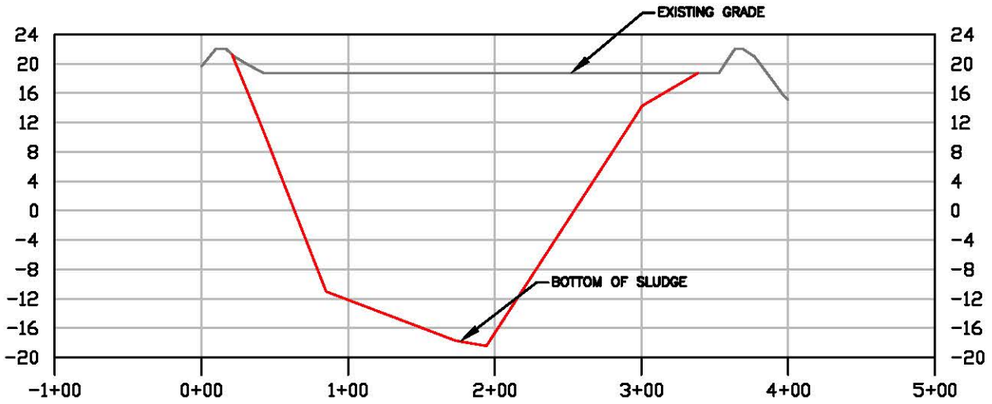
DRAWN BY	J. HOUGH	APPROVED BY	G. TUNSTALL	REV	
DATE	10-20-14	DATE	10-20-14	SHEET NO.	17 OF 21
DRAWING NO.		FIGURE NO.	17	PROJECT NO.	F7998



A 4|5 SLUDGE PIT SECTION



C 4|5 OIL PIT SECTION



B 4|5 SLUDGE PIT SECTION

HORIZONTAL SCALE
0' 50' 100' 150'

VERTICAL SCALE
0' 10' 20' 30'

NOTES:

1. THIS DRAWING WAS CREATED BASED ON PHOTOGRAMMATIC SURVEY DATA COLLECTED BY DALLAS AERIAL SURVEYS, INC. ON 10/29/10 AS REQUESTED BY ENTACT.
2. THE INFORMATION PRESENTED HEREIN IS CONFIDENTIAL IN NATURE AND IS NOT TO BE REPRODUCED OR RE-USED WITHOUT THE EXPRESSED WRITTEN PERMISSION OF ENTACT.

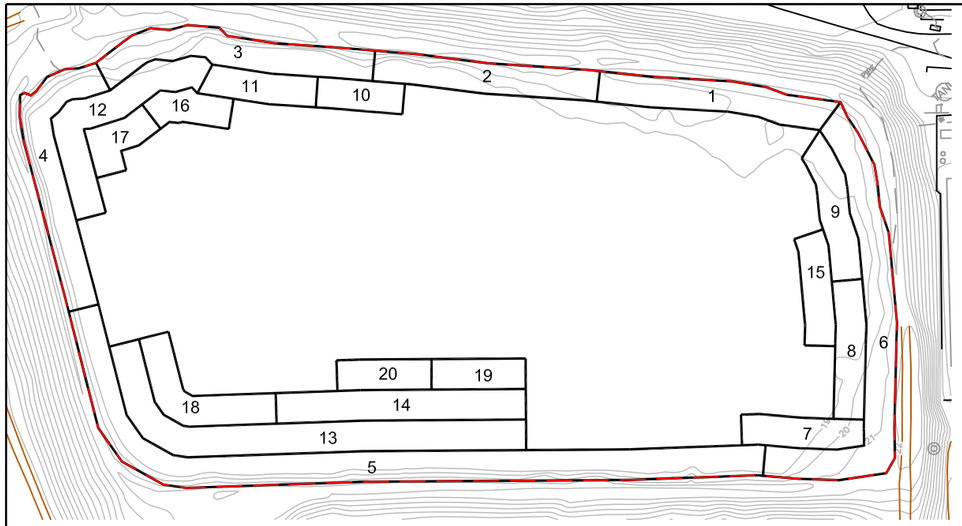
REV	DATE	BY	CHK'D	APR'VD	DESCRIPTION

ENTACT
699 South Friendswood Dr., Suite 101
Friendswood, Texas 77546
P: 281-996-9892

DRAWING NAME: DRAWING 18
SLUDGE REMEDIATION AREAS - CROSS SECTIONS

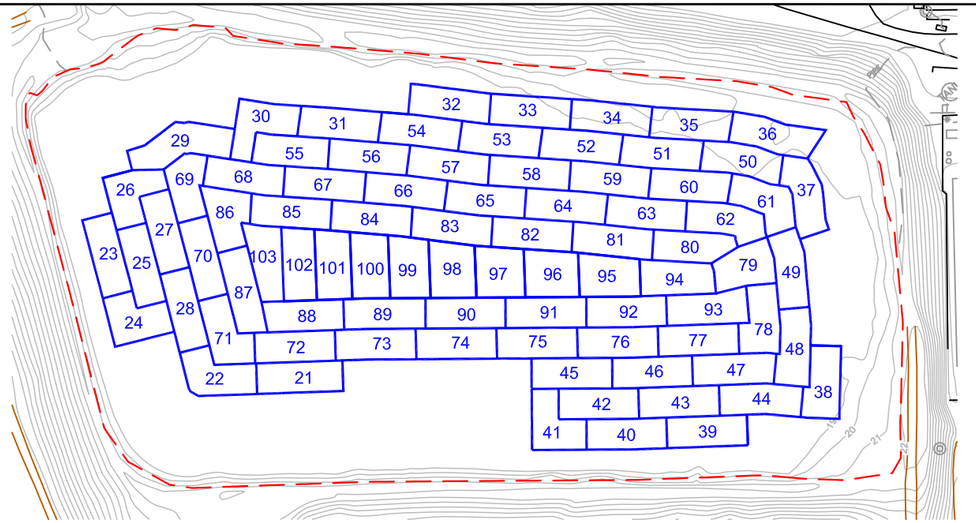
PROJECT NAME & LOCATION: MALONE SERVICE COMPANY SUPERFUND SITE
TEXAS CITY, TEXAS

DRAWN BY	J. HOUGH	APPROVED BY	G. TUNSTALL	REV	
DATE	10-20-14	DATE	10-20-14	SHEET NO.	18 OF 21
DRAWING NO.		FIGURE NO.	18	PROJECT NO.	P7888



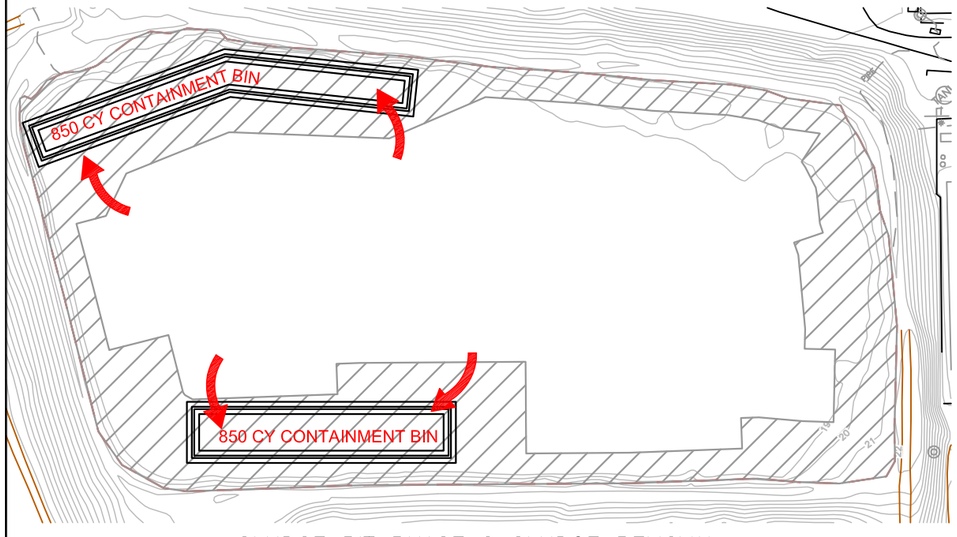
SLUDGE PIT PHASE 1 PERIMETER TREATMENT

(PERIMETER GRIDS IN-SITU TREATMENT TO A MAXIMUM DEPTH OF 14.0 FT.)



SLUDGE PIT PHASE 3 INTERIOR TREATMENT

(INTERIOR GRIDS IN-SITU TREATMENT TO THE REMAINING 14.0 FT OF SLUDGE DEPTH)



SLUDGE PIT PHASE 2 SLUDGE REMOVAL

(REMOVE INTERIOR SLUDGE TO A REMAINING SLUDGE DEPTH OF 14.0 FT., REMOVED SLUDGE WILL BE TREATED IN TOP MIXES OR WITHIN THE API UNITS INSIDE THE SLUDGE PIT LIMITS)

Solidification Mixing Grids

Grid ID	Maximum Grid Width (ft)	Grid Treatment Depth (ft)	Grid Length Required (ft)	Grid Volume (cy)	Soil Bulk Density (γ = pcf)	PC Needed at 10% Addition by Weight (ton)	CaO Need 10% Additi Weight (t
Phase I							
1	25	5.0	184	850	72.30	83.0	83.0
2	25	5.0	184	850	72.30	83.0	83.0
3	25	4.0	230	850	72.30	83.0	83.0
4	25	4.0	230	850	72.30	83.0	83.0
5	25	1.5	612	850	72.30	83.0	83.0
6	25	2.5	367	850	72.30	83.0	83.0
7	25	9.0	102	850	72.30	83.0	83.0
8	25	8.0	115	850	72.30	83.0	83.0
9	25	8.0	115	850	72.30	83.0	83.0
10	25	14.0	66	850	72.30	83.0	83.0
11	25	10.0	92	850	72.30	83.0	83.0
12	25	4.5	204	850	72.30	83.0	83.0
13	25	2.5	367	850	72.30	83.0	83.0
14	25	4.5	204	850	72.30	83.0	83.0
15	25	10.5	87	850	72.30	83.0	83.0
16	25	12.0	77	850	72.30	83.0	83.0
17	25	12.0	77	850	72.30	83.0	83.0
18	25	6.5	141	850	72.30	83.0	83.0
19	25	12.0	77	850	72.30	83.0	83.0
20	25	12.0	77	850	72.30	83.0	83.0
			Total:	17,000	NA	1659.3	1659.

Solidification Mixing Grids

Grid ID	Maximum Grid Width (ft)	Grid Treatment Depth (ft)	Grid Length Required (ft)	Grid Volume (cy)	Soil Bulk Density (γ = pcf)	PC Needed at 10% Addition by Weight (ton)	CaO Needed at 10% Addition by Weight (ton)	Fly Ash Needed at 20% Addition by Weight (ton)
Phase II - Difference between total volume to be treated, 149,500 cy, and the sum of the sludge volume in phases I and III				61,950	72.30	6046.6	6046.6	12093.3

Solidification Mix

Grid ID	Maximum Grid Width (ft)	Grid Treatment Depth (ft)	Grid Length Required (ft)	Grid Volume (cy)	Soil Bulk Density (γ = pcf)	ds Needed at Addition by ight (ton)	CaO Needed at 10% Addition by Weight (ton)	Fly Ash Needed at 20% Addition by Weight (ton)
Phase III								
21	25	14.0	66	850	72.30	83.0	83.0	165.9
22	25	14.0	66	850	72.30	83.0	83.0	165.9
23	25	14.0	66	850	72.30	83.0	83.0	165.9
24	25	14.0	66	850	72.30	83.0	83.0	165.9
25	25	14.0	66	850	72.30	83.0	83.0	165.9
26	25	14.0	66	850	72.30	83.0	83.0	165.9
27	25	14.0	66	850	72.30	83.0	83.0	165.9
28	25	14.0	66	850	72.30	83.0	83.0	165.9
29	25	14.0	66	850	72.30	83.0	83.0	165.9
30	25	14.0	66	850	72.30	83.0	83.0	165.9
31	25	14.0	66	850	72.30	83.0	83.0	165.9
32	25	14.0	66	850	72.30	83.0	83.0	165.9
33	25	14.0	66	850	72.30	83.0	83.0	165.9
34	25	14.0	66	850	72.30	83.0	83.0	165.9
35	25	14.0	66	850	72.30	83.0	83.0	165.9
36	25	14.0	66	850	72.30	83.0	83.0	165.9
37	25	14.0	66	850	72.30	83.0	83.0	165.9
38	25	14.0	66	850	72.30	83.0	83.0	165.9
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45	25	14.0	66	850	72.30	83.0	83.0	165.9
46	25	14.0	66	850	72.30	83.0	83.0	165.9
47	25	14.0	66	850	72.30	83.0	83.0	165.9
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88	25	14.0	66	850	72.30	83.0	83.0	165.9
89	25	14.0	66	850	72.30	83.0	83.0	165.9
90	25	14.0	66	850	72.30	83.0	83.0	165.9
91	25	14.0	66	850	72.30	83.0	83.0	165.9
92	25	14.0	66	850	72.30	83.0	83.0	165.9
93	25	14.0	66	850	72.30	83.0	83.0	165.9
94	Odd shaped area			850	72.30	83.0	83.0	165.9
95	Odd shaped area			850	72.30	83.0	83.0	165.9
96	Odd shaped area			850	72.30	83.0	83.0	165.9
97	Odd shaped area			850	72.30	83.0	83.0	165.9
98	Odd shaped area			850	72.30	83.0	83.0	165.9
99	Odd shaped area			850	72.30	83.0	83.0	165.9
100	Odd shaped area			850	72.30	83.0	83.0	165.9
101	Odd shaped area			850	72.30	83.0	83.0	165.9
102	Odd shaped area			850	72.30	83.0	83.0	165.9
103	Odd shaped area			850	72.30	83.0	83.0	165.9
			Total:	70,550	NA	6886.0	6886.0	13772.1
			Total volume of sludge and reagents:	149,500	NA	14591.9	14591.9	29183.9

LEGEND:

EXISTING GRADE CONTOUR — 10 —

LIMITS OF SLUDGE PIT - - - - -

PHASE 1 SOLIDIFICATION GRID 1

PREVIOUSLY TREATED SLUDGE

PHASE 3 SOLIDIFICATION GRID 1

NOTES:

1. THIS DRAWING WAS CREATED BASED ON PHOTOGRAMMATIC SURVEY DATA COLLECTED BY DALLAS AERIAL SURVEYS, INC. ON 10/29/10 AS REQUESTED BY ENTACT.
2. THE INFORMATION PRESENTED HEREIN IS CONFIDENTIAL IN NATURE AND IS NOT TO BE REPRODUCED OR RE-USED WITHOUT THE EXPRESSED WRITTEN PERMISSION OF ENTACT.

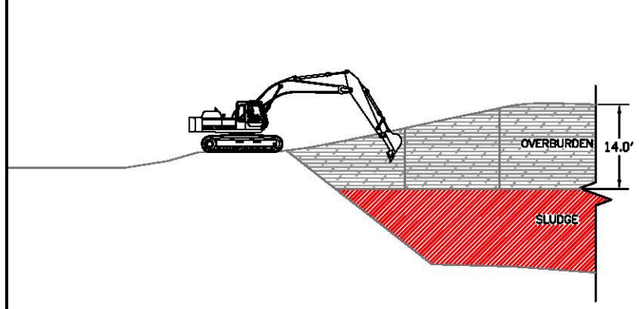
REV	DATE	BY	CHK'D	APR'VD	DESCRIPTION

ENTACT
699 South Friendswood Dr., Suite 101
Friendswood, Texas 77546
P: 281-996-9892

DRAWING NAME: DRAWING 19
SLUDGE PIT SOLIDIFICATION TREATMENT APPROACH

PROJECT NAME & LOCATION: MALONE SERVICE COMPANY SUPERFUND SITE
TEXAS CITY, TEXAS

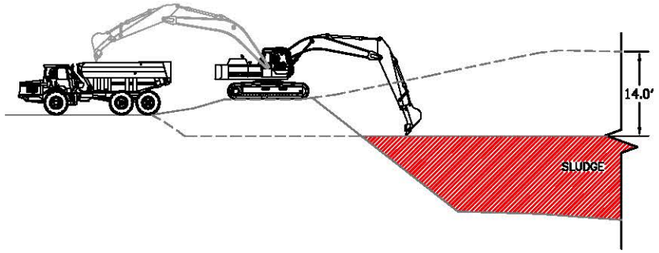
DRAWN BY	J. HOUGH	APPROVED BY	G. TUNSTALL	REV	
DATE	10-20-14	DATE	10-20-14	SHEET NO.	19 OF 21
DRAWING NO.		FIGURE NO.	19	PROJECT NO.	P7888



OIL PIT SOLIDIFICATION – PHASE 1

- TREAT UPPER 14.0 FT. OF OVERBURDEN AND SLUDGE IN–SITU

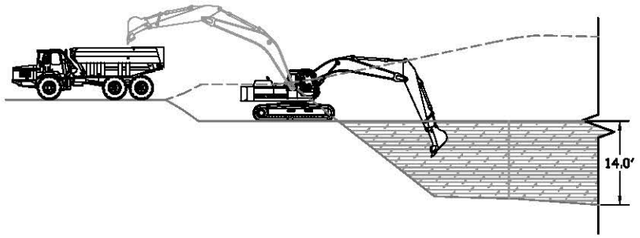
LOAD–OUT TREATED SOILS TO CELL



OIL PIT SOLIDIFICATION – PHASE 2

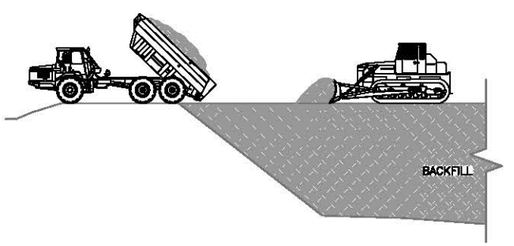
- EXCAVATE TOP 14.0 FT. OF TREATED SLUDGE, TRANSPORT TO CELL
- EXCAVATE BENCH FOR EXCAVATOR

LOAD–OUT TREATED SOILS TO CELL



OIL PIT SOLIDIFICATION – PHASE 3

- TREAT REMAINING SLUDGE TO DEPTH, IN–SITU
- EXCAVATE LOWER TREATED SLUDGE TO DEPTH, TRANSPORT TO CELL



OIL PIT SOLIDIFICATION – PHASE 4

- PLACE BACKFILL MATERIAL OR LEAVE OPEN IF DIRECTED

NOTES:

1. THIS DRAWING WAS CREATED BASED ON PHOTOGRAMMATIC SURVEY DATA COLLECTED BY DALLAS AERIAL SURVEYS, INC. ON 10/29/10 AS REQUESTED BY ENTACT.
2. THE INFORMATION PRESENTED HEREIN IS CONFIDENTIAL IN NATURE AND IS NOT TO BE REPRODUCED OR RE–USED WITHOUT THE EXPRESSED WRITTEN PERMISSION OF ENTACT.

LEGEND:

EXISTING GRADE CONTOUR — 10

LIMITS OF OIL PIT

PHASE 1 SOLIDIFICATION GRID

PHASE 3 SOLIDIFICATION GRID

PHASE 4 BACKFILL AREA

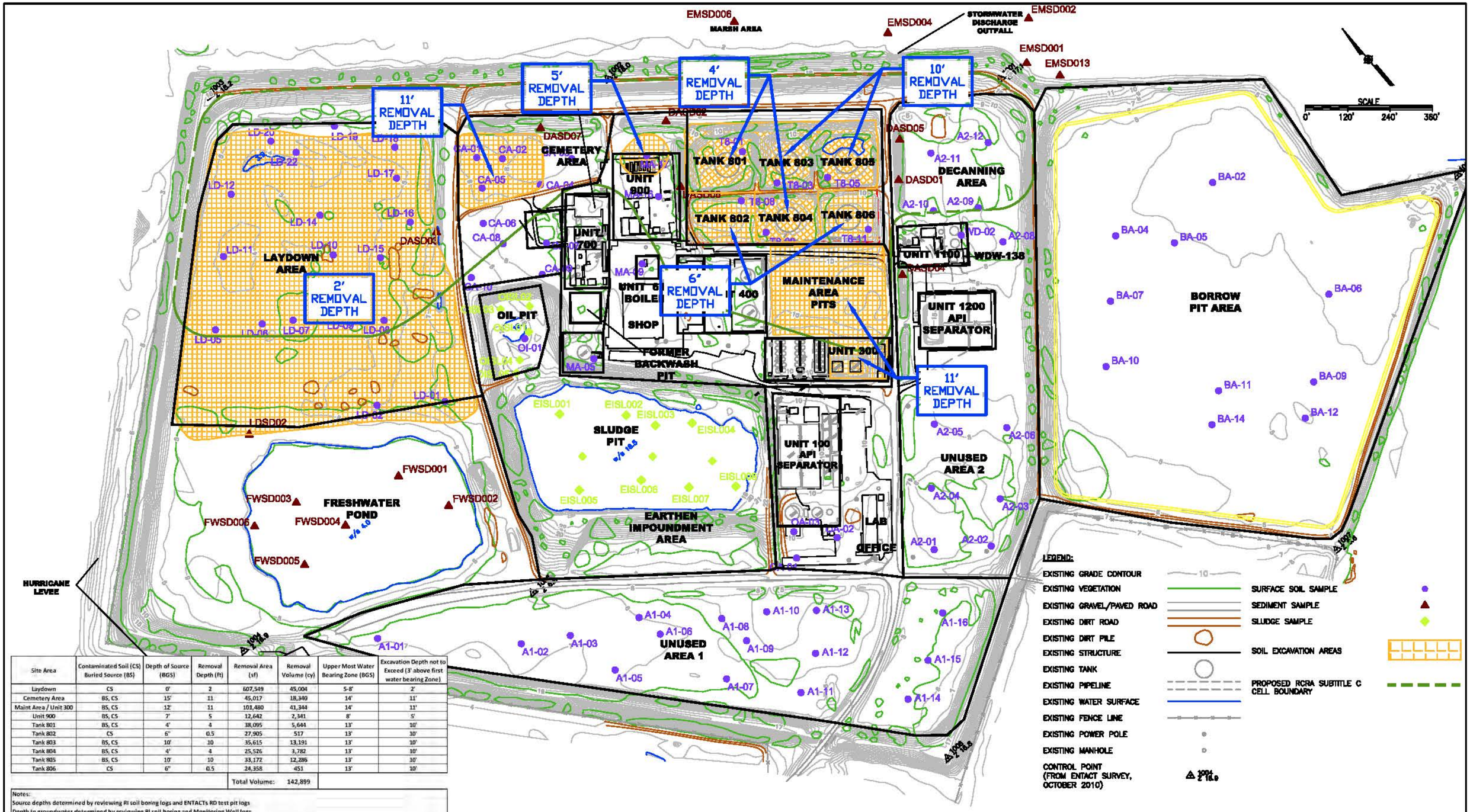
REV	DATE	BY	CHK'D	APR'VD	DESCRIPTION

ENTACT
699 South Friendswood Dr., Suite 101
Friendswood, Texas 77546
P: 281–996–9892

DRAWING NAME: DRAWING 20
OIL PIT SOLIDIFICATION TREATMENT APPROACH

PROJECT NAME & LOCATION: MALONE SERVICE COMPANY SUPERFUND SITE
TEXAS CITY, TEXAS

DRAWN BY	J. HOUGH	APPROVED BY	G. TUNSTALL	REV	
DATE	10–20–14	DATE	10–20–14	SHEET NO.	20 OF 21
DRAWING NO.		FIGURE NO.	20	PROJECT NO.	P7888



Site Area	Contaminated Soil (CS) Buried Source (BS)	Depth of Source (BGS)	Removal Depth (ft)	Removal Area (sf)	Removal Volume (cy)	Upper Most Water Bearing Zone (BGS)	Excavation Depth not to Exceed (3' above first water bearing Zone)
Laydown	CS	0'	2	607,549	45,004	5-8'	2'
Cemetery Area	BS, CS	15'	11	45,017	18,340	14'	11'
Maint Area / Unit 300	BS, CS	12'	11	101,480	41,344	14'	11'
Unit 900	BS, CS	7'	5	12,642	2,341	8'	5'
Tank 801	BS, CS	4'	4	38,095	5,644	13'	10'
Tank 802	CS	6"	0.5	27,905	517	13'	10'
Tank 803	BS, CS	10'	10	35,615	13,191	13'	10'
Tank 804	BS, CS	4'	4	25,526	3,782	13'	10'
Tank 805	BS, CS	10'	10	33,172	12,286	13'	10'
Tank 806	CS	6"	0.5	24,358	451	13'	10'
				Total Volume:	142,899		

Notes:
Source depths determined by reviewing RI soil boring logs and ENTACTs RD test pit logs
Depth to groundwater determined by reviewing RI soil boring and Monitoring Well logs
Areas with only contaminated soil will not exceed excavation of 2' bgs
Source material excavation beyond indicated excavation depths will cease upon visual removal or at 3' above uppermost groundwater bearing zone

NOTES:

1. THIS DRAWING WAS CREATED BASED ON PHOTOGRAMMATIC SURVEY DATA COLLECTED BY DALLAS AERIAL SURVEYS, INC. ON 10/29/10 AS REQUESTED BY ENTACT.

REV	DATE	BY	CHK'D	APP'VD	DESCRIPTION

ENTACT
699 South Friendswood Dr., Suite 101
Friendswood, Texas 77546
P: 281-996-9892

DRAWING NAME: DRAWING 21
SOIL EXCAVATION AREAS

PROJECT NAME & LOCATION: MALONE SERVICE COMPANY SUPERFUND SITE
TEXAS CITY, TEXAS

DRAWN BY	J. HOUGH	APPROVED BY	G. TUNSTALL	REV	
DATE	2-9-15	DATE	2-9-15	SHEET NO.	1 OF 1
DRAWING NO.		FIGURE NO.	2	PROJECT NO.	E7666

EXHIBIT 2
TECHNICAL SPECIFICATIONS

LIST OF SPECIFICATIONS

02060	Aggregates
02071	Geotextile
02072	Geosynthetic Clay Liner (GCL)
02073	Geonet and Geocomposites
02075	Geomembranes
02210	Sludge Solidification
02300	General Earthwork
02302	Waste Placement and Compaction
02500	Surveying
02610	High-Density Polyethylene (HDPE) Pipes and Fittings
02920	Seeding

SECTION 02060
AGGREGATES

SECTION 02060

AGGREGATES

PART 1 GENERAL

1.01 SECTION INCLUDES

A. The Contractor will furnish all labor, materials, tools, supervision, transportation, and installation equipment necessary for the construction of aggregate components of the work as specified herein and as shown on the Drawings.

B. The work of this Section will include the leachate collection and leak detection sumps, leachate chimney drain, leachate collection and leak detection corridors, and gas vent aggregates. The work of this Section also includes dewatering and protection of the work.

1.02 RELATED SECTIONS

A. Section 02071 - Geotextile

B. Section 02072 - Geosynthetic Clay Liner

C. Section 02073 - Geonet and Geocomposites

D. Section 02075 - Geomembranes

E. Section 02300 - General Earthwork

F. Section 02610 - High Density Polyethylene (HDPE) Pipes and Fittings

1.03 REFERENCES

A. Latest version of American Society for Testing and Materials (ASTM) standards:
   1. ASTM C136. Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.
   2. ASTM D422. Standard Test Method for Particle-Size Analysis of Soils.
   3. ASTM D698. Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3)).
   4. ASTM D6938. Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth).

B. Construction Quality Assurance (CQA) Plan.

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1.04 CONSTRUCTION QUALITY ASSURANCE

A. Construction of the aggregate components of the cell project will be performed as outlined in the CQA Plan.

B. The Contractor will be aware of the activities set forth in the CQA Plan and will account for these activities in the construction schedule.

1.05 EXISTING CONDITIONS

A. The Contractor will comply with applicable regulations in locating and providing clearance for all underground and above ground utilities prior to beginning construction activities.

PART 2 PRODUCTS

2.01 AGGREGATES

A. The leachate collection and leak detection sumps, leachate chimney drain, and the leachate collection and leak detection corridors aggregate will consist of hard, strong, durable, natural particles which are free of debris, metals, organic material, and other foreign objects or otherwise deleterious material. The aggregate will meet the following particle size requirements:

- Maximum particle size will be 1-1/2 inches.
- Between 0 and 5 percent passing a 3/8 inch sieve.
- Less than 3 percent passing a No. 200 sieve.

The intent of this specification is to allow an aggregate gradation consistent with AASHTO #57 stone, but other blends meeting the particle sizes specified herein may be used.

B. The gas vent aggregate will consist of hard, strong, durable particles which are free of debris, vegetation, organic material, sharp objects, foreign objects, and other deleterious material. The aggregate will be 3/8-inch (nominal) pea gravel with less than 3 percent passing a No. 200 sieve.

2.02 EQUIPMENT

A. The Contractor will furnish, operate, and maintain grading equipment as is necessary to produce uniform layers, sections, and smoothness of grade for compaction and drainage.

PART 3 EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any of the work described in this Section, the Contractor will become thoroughly familiar with the site, the site conditions, and all portions of the work falling within this Section.

B. Prior to implementing any of the work in this Section, the Contractor will carefully inspect the installed work of all other Sections and verify that all work is complete to the point where the work of this Section may properly commence without adverse impact.

3.02 EROSION PROTECTION AND SEDIMENT CONTROL

A. Prior to implementing any of the work described in this Section, the Contractor will install erosion and sediment controls features surrounding and down-gradient from related construction areas. The Contractor will maintain all erosion protection and sediment control features throughout construction.

3.03 PLACEMENT OF AGGREGATE

A. The Contractor will place aggregate to the thickness, elevations, and locations indicated on the Drawings.

B. Aggregate will be carefully placed to avoid disturbance or damage of underlying geosynthetics.

3.04 SURVEYING AND CONSTRUCTION TOLERANCES

A. The top elevations of aggregate surfaces will be constructed within ±0.2 feet of the grades shown on the Drawings, provided that all minimum thicknesses are met.

3.05 PROTECTION OF WORK

A. The Contractor will use all means necessary to protect all prior work, including all materials and completed work of other Sections.

B. In the event of damage, the Contractor will immediately make all repairs and replacements necessary.

[END OF SECTION]

SECTION 02071
GEOTEXTILE

SECTION 02071

GEOTEXTILE

PART 1 GENERAL

1.01 SECTION INCLUDES

A. The Geosynthetics Manufacturer will supply the geotextile for the use in the leachate collection and leak detection sumps, leachate collection corridor, chimney drain, and gas vent areas, as shown on the Drawings.

B. The Contractor will furnish all labor, materials, tools, supervision, transportation, and equipment to install the geotextile, including, but not limited to layout, sewing, patching, and testing, and all necessary and incidental items required to complete the work in accordance with the Drawings and these Specifications.

1.02 RELATED SECTIONS

A. Section 02060 - Aggregates

B. Section 02073 – Geonet and Geocomposites

C. Section 02300 - General Earthwork

1.03 REFERENCES

A. Latest version of American Society for Testing and Materials (ASTM) Standards:
   1. ASTM D4355. Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus.
   2. ASTM D4491. Standard Test Methods for Water Permeability of Geotextiles by Permittivity.
   3. ASTM D4533. Standard Test Method for Trapezoid Tearing Strength of Geotextiles.
   4. ASTM D4632. Standard Test Method for Grab Breaking Load and Elongation of Geotextiles.
   5. ASTM D4751. Standard Test Method for Determining Apparent Opening Size of a Geotextile.
   6. ASTM D4873. Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples.
   7. ASTM D6241. Standard Test Method for Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50-mm Probe.

B. Construction Quality Assurance (CQA) Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. Installation of the geotextile components of the project, while not part of the formal CQA program, will be periodically monitored by the QA/QC Manager.

PART 2 PRODUCTS

2.01 MATERIALS

A. Geotextile will be made of polyester or polypropylene.

B. Geotextile used will meet, at a minimum, the standards included in Table 02071-1.

C. Furnished geotextile will be stock products.

2.02 MANUFACTURING QUALITY CONTROL

A. Geotextiles will be manufactured with quality control procedures that meet generally accepted industry standards.

B. The Geosynthetics Manufacturer will sample and test the geotextile to demonstrate that the material conforms to the requirements of this Section and values specified in Table 02071-1.

C. The Geosynthetics Manufacturer will submit quality control certificates signed by the Geosynthetics Manufacturer quality control manager. The quality control certificates will include:
   1. lot, batch, and roll number and identification; and
   2. results of manufacturing quality control tests including description of test methods used.

D. Any geotextile sample that does not comply with this Section will result in rejection of the roll from which the sample was obtained. The Geosynthetics Manufacturer will replace any rejected rolls at no additional cost to MCP.

E. If a geotextile sample fails to meet the quality control requirements of this Section, the Geosynthetics Manufacturer will sample and test each roll manufactured in the same lot or batch, or at the same time, as the failing roll. Sampling and testing of rolls will continue until a pattern of acceptable test results is established (e.g., failing rolls bracketed by passing rolls).

F. Additional sample testing may be performed, at the Geosynthetics Manufacturer's discretion and expense, to more closely identify any non-complying rolls and/or to qualify individual rolls.

G. Sampling will, in general, be performed on sacrificial portions of the geotextile material such that repair is not required. The Geosynthetics Manufacturer will sample and test the geotextile at the frequencies presented in these Specifications and ensure that its properties conform to the specified values.

2.03 PACKAGING AND LABELING

A. Geotextile will be supplied in rolls wrapped in opaque and relatively impermeable protective covers. Wrapping which becomes torn or damaged will be repaired with similar materials.

B. Geotextile rolls will be marked or tagged in accordance with ASTM D4873 with the following information:
   1. manufacturer's name;
   2. product identification;
   3. lot or batch number;
   4. roll number; and
   5. roll dimensions.

C. Geotextile rolls not labeled in accordance with this Section or on which labels are illegible will be rejected, removed from the jobsite, and replaced with properly labeled rolls.

2.04 TRANSPORTATION

A. Transportation of the geotextile will be the responsibility of the Geosynthetics Manufacturer. The Geosynthetics Manufacturer will be liable for all damages to the materials incurred prior to and during transportation to the site.

B. Geotextile will be delivered to the site at least 14 calendar days prior to the planned deployment date to allow adequate time to perform conformance testing (if required) on the geotextile samples.

2.05 HANDLING AND STORAGE

A. The Contractor will be responsible for unloading the geotextile rolls delivered to the site, and for placing them in the designated storage area.

B. Once the geotextile is unloaded at the site and placed in the designated storage area, the Contractor will be responsible for all additional geotextile unloading, handling, storage and care at the site. The geotextile will be stored off the ground and out of direct sunlight, and will be protected from excessive heat or cold, mud, dirt, and dust or other damaging or deleterious conditions. Any additional storage procedures required by the manufacturer will be the Contractor’s responsibility.

PART 3 EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any of the work in this Section, the Contractor will carefully inspect the installed work of all other Sections and verify that all work is complete to the point where the work of this Section may properly commence without adverse impact.

3.03 HANDLING AND PLACEMENT

A. The Contractor will handle geotextile in such a manner as to ensure they are not damaged in any way.

B. The Contractor will take necessary precautions to prevent damage to underlying layers including rutting during placement of the geotextile.

C. After unwrapping the geotextile from its opaque cover, the Contractor as appropriate will not leave them exposed for a period in excess of 30 calendar days.

D. If white colored geotextile is used, take precautions against "snowblindness" of personnel.

E. In the presence of wind, all geotextile will be weighted by the Contractor with sandbags or the equivalent until the overlying layer is placed.

3.04 SEAMS AND OVERLAPS

A. In general, no horizontal seams or splices are allowed on side slopes greater than 5%, except as part of a patch. A splice is defined as a seam connecting the ends of two rolls.

B. Geotextile can be overlapped 6 inches and either seamed with polymeric thread with properties equal or exceeding those of the geotextile or thermally bonded.

C. During geotextile installation and seaming, the Contractor’s seaming technician will observe for and remove any missing/broken needles that occur during seaming.

3.05 REPAIRS

A. Any holes or tears in the geotextile will be repaired by sewing a patch made from the same geotextile over the affected area, with a minimum 12 inch overlap in all directions.

B. During geotextile repairs, the Contractor’s seaming technician will observe for and remove any missing/broken needles that occur during sewing of the repair.

3.06 PLACEMENT OF OVERLYING MATERIALS

A. The Contractor will place materials on top of geotextile (e.g., aggregates, pipes, soil) in such a manner as to ensure that:
   1. the geotextile and underlying materials are not damaged or displaced;
   2. minimal slippage occurs between the geotextile and the underlying layers; and
   3. excess stresses are not produced in the geotextile.

B. Equipment will not be operated directly on the geotextile. The Contractor will only operate equipment above the geotextile that meets the following ground pressure requirements.

Allowable Equipment Ground Pressure (psi)	**Thickness of Overlying Soil (in.)**
<5	12
<10	18
<20	24
>20	36

3.07 PROTECTION OF WORK

A. The Contractor will use all means necessary to protect all prior work, including all materials and completed work of other Sections.

TABLE 02071-1
MATERIAL SPECIFICATIONS FOR NONWOVEN GEOTEXTILE

PROPERTY	QUALIFIER	UNITS	SPECIFIED VALUES (1)	TEST METHOD	MQC TESTING FREQUENCY
Type			Nonwoven		
Mass Per Unit Area	minimum	oz/yd^2	8	ASTM D5261	1 per 100,000 ft^2 (min. 1 per lot)
Apparent Opening Size (O_{95})	maximum	inches	0.008	ASTM D4751	1 per 540,000 ft^2 (min. 1 per lot)
Grab Tensile Strength	minimum	lbs	160	ASTM D4632	1 per 100,000 ft^2 (min. 1 per lot)
Trapezoidal Tear Strength	minimum	lbs	60	ASTM D4533	1 per 100,000 ft^2 (min. 1 per lot)
Puncture Strength	minimum	lbs	315	ASTM D6241	1 per 100,000 ft^2 (min. 1 per lot)
Water Permeability	minimum	cm/s	0.10	ASTM D4491	1 per 540,000 ft^2 (min. 1 per lot)
UV Resistance	minimum	percent	70	ASTM D4355	Per formulation

Notes:

(1) All values represent minimum average roll values.

(2) Specified test methods and parameters may be modified by the Engineer to be consistent with changes to the industry standard for the specified type of nonwoven geotextile.

[END OF SECTION]

SECTION 02072
GEOSYNTHETIC CLAY LINER

SECTION 02073

GEOSYNTHETIC CLAY LINER

PART 1 GENERAL

1.01 SECTION INCLUDES

A. The Geosynthetics Manufacturer will supply the geosynthetic clay liner (GCL) for the liner system and the final cover system.

B. The Contractor will furnish all labor, materials, tools, supervision, transportation, and equipment to install the GCL, including but not limited to layout, patching, and testing, installation, and all necessary and incidental items required to complete the work in accordance with the Drawings and these Specifications.

1.02 RELATED SECTIONS

A. Section 02060 - Aggregates

B. Section 02071 - Geotextile

C. Section 02073 – Geonet and Geocomposites

D. Section 02075 - Geomembranes

E. Section 02300 - General Earthwork

F. Section 02610 - High Density Polyethylene (HDPE) Pipes and Fittings

1.03 REFERENCES

A. Latest version of American Society for Testing and Materials (ASTM) standards:

1. ASTM D5887. Standard Test Methods for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter.
2. ASTM D5890. Standard Test Methods for Swell Index of Clay Mineral Component of Geosynthetic Clay Liners.
3. ASTM D5891. Standard Test Method for Fluid Loss of Clay Component of Geosynthetic Clay Liners.
4. ASTM D5993. Standard Test Method for Measuring Mass Per Unit Area of Geosynthetic Clay Liners.
5. ASTM D6768. Standard Test Method for Tensile Strength of Geosynthetic Clay Liners.

B. Construction Quality Assurance (CQA) Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. The installation of the GCL will be monitored as outlined in the CQA Plan.

B. The Contractor will be aware of the activities set forth in the CQA Plan and will account for these activities in the construction schedule.

PART 2 PRODUCTS

2.01 MATERIALS

A. The Geosynthetics Manufacturer will furnish GCL materials that conform to the following requirements.

1. On the liner system sideslopes (liner slopes ≥ 5%) and final cover system sideslopes (cover slopes ≥ 5.8%), the GCL will consist of a , reinforced bentonite composite (needle-punched or stitch-bonded GCL with fibers, yarns, or threads passed through the GCL materials to increase internal shear strength) with nonwoven geotextile and woven geotextile backings.
2. On the liner system floor (liner slopes < 5%) and final cover system top areas (cover slopes < 5.8%), the GCL will be the same as listed above for sloped areas, except that it is allowed to be either reinforced or unreinforced.
3. The GCL properties will comply with the required values shown in Table 02072-1.

2.02 MANUFACTURING QUALITY CONTROL

A. The Geosynthetics Manufacturer will implement a quality control (MQC) program for materials related to GCL manufacturing, which will include MQC sampling and testing to demonstrate the GCL quality and suitability for use.

B. The required MQC tests, methods, and frequencies are presented in Table 02072-1.

C. Prior to shipping, the Geosynthetics Manufacturer will provide the required MQC information presented in Table 02072-1. Any sample that does not comply with the requirements will result in rejection of the roll from which the sample was obtained.

D. Prior to shipping, the Geosynthetics Manufacturer will provide a certification that the GCL has been continuously inspected using metal detectors and found to be needle free.

2.03 PACKAGING AND LABELING

A. GCL will be supplied in rolls wrapped in weather-resistant opaque protective covers. Wrapping which become torn or damaged will be replaced with similar materials.

B. GCL rolls will be labeled with the following information.
   1. manufacturer's name;
   2. product identification;
   3. lot or batch number;
   4. roll number; and
   5. roll dimensions.

C. GCL rolls, which cannot be identified per above because of missing, illegible, or damaged labels, will be removed from the jobsite and replaced with properly labeled rolls.

D. If any special handling is required, it will be so marked on the geotextile component e.g., "This Side Up" or "This Side Against Soil To Be Retained".

2.04 TRANSPORTATION

A. Transportation of the GCL will be the responsibility of the Geosynthetics Manufacturer. The Geosynthetics Manufacturer will be liable for all damages to the materials incurred prior to and during transportation to the site.

B. GCL will be delivered to the site at least 14 calendar days prior to the planned deployment date to allow adequate time to perform sampling for conformance testing (if sampling done at the site) on the GCL samples.

2.05 HANDLING AND STORAGE

A. The Contractor will be responsible for unloading the GCL rolls delivered to the site, and for placing them in the designated storage area.

B. The GCL will be stored off the ground and out of direct sunlight, and will be protected from excessive heat or cold, mud, dirt, and dust or other damaging or deleterious conditions. The GCL rolls will also be kept in their water resistant covering to avoid exposure to the elements (precipitation, humidity, UV exposure) and ultimately to prevent premature hydration or damage. Any additional storage procedures required by the Geosynthetics Manufacturer will be the Contractor's responsibility.

PART 3 – EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any of the work in this Section, the Contractor will carefully inspect the installed work of all other Sections and verify that all work is complete to the point where the work of this Section may properly commence without adverse impact.

3.02 CONFORMANCE TESTING

A. Conformance sampling and testing requirements for the GCL are presented in Table 02072-2.

B. Conformance sampling may be performed either at the manufacturing plant or upon delivery of rolls to the site, as requested by the Contractor. Conformance samples will be taken across the entire roll width. All conformance test results will be reviewed by the QA/QC Manager prior to deployment of the material. When a sample fails a conformance test, the material from the lot represented by the failing test should be considered out-of-specification and rejected.

C. Additional conformance samples may be taken to isolate the portion of the lot not meeting the specifications. To isolate the out-of-specification material, two additional conformance samples should be taken from the closest numerical roll numbers to the failing sample. If both samples pass, only the initial failed roll will be rejected. If any one of the additional tests fails, then the entire lot will be rejected and the procedure may be repeated with additional tests to further bracket the failing rolls within the lot.

3.03 HANDLING AND PLACEMENT

A. The Contractor will not commence GCL installation until the onsite QA/QC Manager completes conformance evaluation of the GCL and quality assurance evaluation of previous work, including evaluation of survey results for previous work.

B. The Contractor will handle all GCL rolls in such a manner as to ensure they are not damaged in any way.

C. The GCL will be installed in accordance with the Geosynthetics Manufacturer's recommendations. The GCL will not be placed during inclement weather such as high winds, rain, or an imminent threat of rain. The GCL will not be allowed to prematurely hydrate.

D. The subgrade surface on which the GCL will be deployed will be relatively smooth and uniform and free of irregularities, dimples, loose soil, or abrupt changes in grade. The subgrade will also be free of standing water or excessive moisture. The subgrade surface will be composed of particles smaller than ¾-inch size, or otherwise have particles larger than ¾-inch dimension removed by hand prior to GCL deployment.

   1. For the liner GCL, it should be recognized that the GCL subgrade refers to the top surface of the 1-ft thick compacted clay liner. The compacted clay liner will be constructed in lifts to within target compaction criteria (moisture and density) as needed using equipment that remolds and kneads the clay to achieve a low-permeability compacted clay liner with a hydraulic conductivity that is no greater than 1×10^{-7} cm/s. The compacted clay liner construction will be documented and tested as required, with these required activities on the clay liner completed in a given area prior to GCL deployment over that area.

E. Prior to GCL deployment, the subgrade will be prepared by rolling with a smooth-drum roller to minimize the surface roughness and press down protruding soil or rock particles.

F. The Contractor will document their acceptance of the subgrade prior to GCL deployment.

1. For the liner GCL, the GCL subgrade refers to the top surface of the 1-ft thick compacted clay liner (having $k \leq 1 \times 10^{-7}$ cm/s). The Contractor will maintain and repair (e.g., keep moistened, prevent desiccation, fill and repair cracks, repair erosion) completed portions of the compacted clay liner prior to liner GCL installation.

G. Personnel working on the GCL will not smoke, wear damaging shoes, or engage in any other activity likely to damage the GCL.

H. On slopes, the GCL panels will be anchored securely and then deployed down-slope in a controlled manner to continually keep the GCL in slight tension and to avoid damage.

I. GCL panels will generally be oriented parallel to the line of maximum slope (i.e., up and down the slope, not across the slope). Horizontal overlap seams on sideslopes should be minimized. In corners and irregular shaped areas, the number of overlap seams should be minimized.

J. The GCL will be deployed with the proper side facing upward, if required as identified on the Drawings or Specifications.

K. During deployment, care should be taken to avoid damaging the underlying subgrade (e.g., rutting, etc.), and to avoid entrapping any stones, moisture, dust, etc. underneath the GCL that could prematurely hydrate the GCL or otherwise cause damage.

L. Folds or excessive slack will not be allowed. Wrinkles will be minimized and removed as much as possible during deployment.

M. If necessary to cut the GCL to properly achieve the panel layout (commonly done using hook-blade cutter), adjacent materials will be protected from potential damage due to cutting.

N. Care will be taken to avoid excess loss of bentonite from the GCL edges.

O. Tools will not be left on, in, or under the GCL.

P. The quantity of GCL deployed during one working day will not exceed the amount that can be covered by geomembrane by the end of the day. Exceptions may be made by the Contractor if dry weather is forecast for several consecutive days. Under all circumstances the GCL will be covered and protected from moisture and precipitation during and after installation.

3.04 SEAMS AND OVERLAPS

A. GCL edges and roll ends will be overlapped following Geosynthetics Manufacturer's recommendations. Additional bentonite will be added to overlaps in accordance with Geosynthetics Manufacturer's specifications.

3.05 REPAIRS

A. If the GCL is damaged (torn, punctured, perforated, and so forth) either the entire GCL must be replaced or the affected area must be repaired by cutting a patch to fit above or below the damaged area. For GCL repairs, the repair will be constructed by removing the damaged portion of the GCL and placing a patch obtained from a new GCL roll and cut to size such that a minimum overlap of 12 inches is achieved around all parts of the damaged area. Dry bentonite or bentonite mastic should be applied around the damaged area prior to placement of the patch. Adhesive or other approved means may be used to affix the patch in place so that it is not displaced during placement of overlying materials.

3.06 PLACEMENT OF OVERLYING MATERIALS

A. The Contractor will place all materials overlying the GCL in such a manner as to ensure that:
   1. the GCL and underlying geosynthetic materials are not damaged;
   2. minimal slippage occurs between the GCL and underlying layers; and
   3. excess stresses are not produced in the GCL.

B. Equipment will not be operated directly on the GCL. The Contractor will only operate equipment above the GCL that meets the following ground pressure requirements.

Allowable Equipment Ground Pressure (psi)	**Thickness of Overlying Soil (in.)**
<5	12
<10	18
<20	24
>20	36

3.07 PROTECTION OF WORK

A. The Contractor will use all means necessary to protect all prior work, including all materials and completed work of other Sections.

TABLE 02072-1
MATERIAL SPECIFICATIONS FOR GEOSYNTHETIC CLAY LINER

PROPERTY	QUALIFIER	UNITS	SPECIFIED VALUES	TEST METHOD	MQC TESTING FREQUENCY
Bentonite					
Bentonite Swell Index	minimum	ml/2g	24	ASTM D5890	1 per 50 tons (min. 1 per rail car)
Fluid Loss	maximum	ml	18	ASTM D5891	1 per 50 tons (min. 1 per rail car)
GCL					
Bentonite Content (Mass/Area), Oven Dried Basis	Minimum	lbs/ft^2	0.75	ASTM D5993	1 per 40,000 ft^2
Tensile Strength, Machine Direction (MD)	Minimum	lb/in.	23	ASTM D6768	1 per 200,000 ft^2
Hydraulic Conductivity	maximum	cm/sec	5×10^{-9}	ASTM D5887	1 per 200,000 ft^2

Notes:

(1) Specified test methods and parameters may be modified by the Project Engineer to be consistent with changes to the industry standard for GCLs.

TABLE 02072-2
CQA CONFORMANCE TESTING REQUIREMENTS FOR GEOSYNTHETIC CLAY LINER

TEST	METHOD	MINIMUM FREQUENCY OF CQA TESTING
Bentonite Content (Mass/Area)	ASTM D5993	1 per 100,000 ft^2
Hydraulic Conductivity	ASTM D5887	1 per 200,000 ft^2

[END OF SECTION]

SECTION 02073
GEONET AND GEOCOMPOSITES

SECTION 02073

GEONET AND GEOCOMPOSITES

PART 1 GENERAL

1.01 SECTION INCLUDES

A. The Geosynthetics Manufacturer will supply the geonet for the liner system floor and geocomposites for the liner system sideslopes and for the final cover system.

B. The Contractor will furnish all labor, materials, tools, supervision, transportation, and equipment to install the geonet and geocomposites, including but not limited to layout, sewing, patching, and testing, installation, and all necessary and incidental items required to complete the work in accordance with the Drawings and these Specifications.

1.02 RELATED SECTIONS

A. Section 02060 - Aggregates

B. Section 02071 - Geotextile

C. Section 02072 - Geosynthetic Clay Liner

D. Section 02075 - Geomembranes

E. Section 02300 - General Earthwork

F. Section 02610 - High Density Polyethylene (HDPE) Pipes and Fittings

1.03 REFERENCES

A. Latest version of American Society for Testing and Materials (ASTM) standards:

1. ASTM D792. Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement.
2. ASTM D1505. Standard Test Method for Density of Plastics by the Density-Gradient Technique.
3. ASTM D4218. Standard Test Method for Deterioration of Carbon Black Content in Polyethylene Compounds By the Muffle-Furnace Technique.
4. ASTM D4355. Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus.
5. ASTM D4491. Standard Test Methods for Water Permeability of Geotextiles by Permittivity.

6. ASTM D4533. Standard Test Method for Trapezoid Tearing Strength of Geotextiles.
7. ASTM D4632. Standard Test Method for Grab Breaking Load and Elongation of Geotextiles.
8. ASTM D4716. Standard Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head.
9. ASTM D4751. Standard Test Method for Determining Apparent Opening Size of a Geotextile.
10. ASTM D5199. Standard Test Method for Measuring the Nominal Thickness of Geosynthetics.
11. ASTM D5261. Standard Test Method for Measuring Mass Per Unit Area of Geotextiles.
12. ASTM D6241 Standard Test Method for Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50-mm Probe.
13. ASTM D7179 Standard Test Method for Determining Geonet Breaking Force.

B. Geosynthetic Research Institute Standard Guide GC-8, Determination of the Allowable Flow Rate of a Drainage Geocomposite.

C. Construction Quality Assurance (CQA) Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. The installation of the geonet and geocomposites will be monitored as outlined in the CQA Plan.

B. The Contractor will be aware of the activities set forth in the CQA Plan and will account for these activities in the construction schedule.

PART 2 PRODUCTS

2.01 MATERIALS

A. The Geosynthetics Manufacturer will furnish geocomposites consisting of a geonet with nonwoven geotextile bonded to one side for the single-sided geocomposite and both sides for the double-sided geocomposite.

B. The Geosynthetics Manufacturer will furnish geonet and geocomposites having properties that comply with the required property values shown in Table 02073-1. Unless otherwise noted, required geonet and geocomposite properties will be considered minimum average roll values (95 percent lower confidence limit). The Geosynthetics Manufacturer will provide test results for these procedures, as well as certification that the materials meet or exceed the specified values.

C. The Geosynthetics Manufacturer will furnish geonet and geocomposites that are stock products.

D. In addition to the property values listed in Table 02073-1, the geocomposites will:
   1. retain their structure during handling, placement, and long-term service; and
   2. be capable of withstanding outdoor exposure for a minimum of 30 days with no measurable deterioration.

E. Requirements for stitching threads: Polymeric thread, with chemical resistance properties equal to or exceeding those of the geotextile component, will be used for all sewing.

2.02 MANUFACTURING QUALITY CONTROL

A. Geonets and geocomposites will be manufactured with quality control procedures that meet generally accepted industry standards.

B. The Geosynthetics Manufacturer will sample and test the geonet and the geotextile and geonet components of the geocomposites to demonstrate that these materials conform to the requirements of this Section and values specified in Table 02073-1.

C. The Geosynthetics Manufacturer will submit quality control certificates signed by the Geosynthetics Manufacturer quality control managers (for geotextile, geonet, and geocomposites). The quality control certificates will include:
   1. lot, batch, and roll number and identification; and
   2. results of manufacturing quality control tests including description of test methods used.

D. Any geonet or geocomposite sample that does not comply with this Section will result in rejection of the roll from which the sample was obtained. The Geosynthetics Manufacturer will replace any rejected rolls at no additional cost.

E. If a geotextile, geonet, or geocomposite sample fails to meet the quality control requirements of this Section, the Geosynthetics Manufacturer will sample and test rolls manufactured at the same time or in the same lot as the failing roll. Sampling and testing of rolls will continue until a pattern of acceptable test results is established (e.g., until the extent of the failing rolls are bracketed by passing rolls).

F. Additional sample testing may be performed, at the Geosynthetics Manufacturer's discretion and expense, to more closely identify any non-complying rolls and/or to qualify individual rolls.

G. Sampling will, in general, be performed on sacrificial portions of the geonet and geocomposite materials such that repair is not required. The Geosynthetics Manufacturer will sample and test the geonet and geocomposites at the frequencies presented in these Specifications and ensure that their properties conform to the specified values.

H. The Geosynthetics Manufacturer will comply with the certification and submittal requirements herein and of the CQA Plan.

2.03 PACKAGING AND LABELING

A. Geonet and Geocomposites will be supplied in rolls wrapped in opaque and relatively impermeable protective covers. Wrapping which become torn or damaged will be replaced with similar materials.

B. Geonet and Geocomposite rolls will be labeled with the following information.
   1. manufacturer's name;
   2. product identification;
   3. lot or batch number;
   4. roll number; and
   5. roll dimensions.

C. Geonet and Geocomposite rolls, which cannot be identified per above because of missing, illegible, or damaged labels, will be removed from the jobsite and replaced with properly labeled rolls.

D. If any special handling is required for geocomposites, it will be so marked on the geotextile component e.g., "This Side Up" or "This Side Against Soil To Be Retained".

2.04 TRANSPORTATION

A. Transportation of the geonet and geocomposites will be the responsibility of the Geosynthetics Manufacturer. The Geosynthetics Manufacturer will be liable for all damages to the materials incurred prior to and during transportation to the site.

B. Geonet and Geocomposite rolls will be delivered to the site at least 14 days prior to the planned deployment date to allow adequate time to perform conformance testing (if required) on the geonet and geocomposite samples.

2.05 HANDLING AND STORAGE

A. The Contractor will be responsible for unloading the geonet and geocomposite rolls delivered to the site, and for placing them in the designated storage area.

B. The geonet and geocomposite rolls will be stored off the ground and out of direct sunlight, and will be protected from excessive heat or cold, mud, dirt, and dust or other damaging or deleterious conditions. Any additional storage procedures required by the manufacturer will be the Contractor's responsibility.

PART 3 – EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any of the work in this Section, the Contractor will carefully inspect the installed work of all other Sections and verify that all work is complete to the point where the work of this Section may properly commence without adverse impact.

3.03 HANDLING AND PLACEMENT

A. The Contractor will not commence geonet and geocomposite installation until the onsite QA/QC Manager completes conformance evaluation of the geonet and geocomposite and quality assurance evaluation of previous work, including evaluation of survey results for previous work.

B. The Contractor will handle all geonet and geocomposites in such a manner as to ensure they are not damaged in any way.

C. The Contractor will take necessary precautions to prevent damage to underlying layers including rutting during placement of the geonet and geocomposites.

D. After unwrapping the geocomposites from their opaque cover, the geocomposites will not be left exposed for a period in excess of 45 days.

E. If white colored geotextiles are used in the geocomposites, precautions will be taken against “snowblindness” of personnel.

F. For geonet and geocomposites with directional hydraulic transmissivity, the Contractor will install the geonet and geocomposites with the high transmissivity direction (usually the roll direction) in the downgradient direction of the liner system and final cover system as appropriate.

G. In the presence of wind, all geocomposites will be weighted by the Contractor with sandbags or the equivalent until the overlying layer is placed.

H. Care will be taken during placement of geocomposites not to entrap dirt or excessive dust in the geocomposites that could cause clogging of the drainage system, and/or stones that could damage the geocomposites. Care will be exercised when handling sandbags, to prevent rupture or damage of the sandbags.

I. If necessary, the geonet and geocomposites will be positioned by hand after being unrolled over a smooth rub sheet to minimize wrinkles.

J. The geonet and geocomposites will only be cut using Manufacturer’s recommended procedures.

K. Tools will not be left on, in, or under the geonet and geocomposites.

3.04 SEAMS AND OVERLAPS

A. The components of the geocomposite (i.e., geotextile, geonet, and geotextile) will not be bonded together at the ends and edges of the rolls. Each component will be secured or seamed to the like component of adjoining panels.

B. Geonet and Geonet Component of the Geocomposites:
   1. The geonet and geonet component of the geocomposites will be overlapped by at least 4 inches. These overlaps will be secured by tying.
   2. Tying will be achieved by plastic fasteners or polymer braid. Tying devices will be white or yellow for easy inspection. Metallic devices will not be used.
   3. Tying will be every 5 feet along the slope, every 2 feet across the slope and every 6 feet on horizontal surfaces.

C. Geotextile Component of the Geocomposites:
   1. For single-sided geocomposite, the top layers of geotextile will be continuously sewn (i.e., spot sewing is not allowed). Geotextiles will be overlapped a minimum of 6 inches prior to seaming.
   2. For double-sided geocomposite, the bottom layers of geotextile will be overlapped. The top layers of geotextile will be continuously sewn (i.e., spot sewing is not allowed). Geotextiles will be overlapped a minimum of 6 inches prior to seaming.
   3. No horizontal seams will be allowed higher than one-third the slope height on slopes steeper than 10 horizontal to 1 vertical.
   4. Polymeric thread, with chemical resistance properties equal to or exceeding those of the geotextile component, will be used for all sewing. The seams will be sewn using Stitch Type 401 per Federal Standard No. 751a. The seam type will be Federal Standard Type SSN-1.

3.05 REPAIRS

A. Any holes or tears in the geocomposites will be repaired by placing a patch extending 2 ft beyond the edges of the hole or tear. The patch will be secured by tying fasteners through the bottom geotextile (not applicable for single-sided geocomposite) and the geonet of the patch, and through the top geotextile and geonet. The patch will be secured every 6 inches with approved tying devices. The top geotextile component of the patch will be heat sealed to the top geotextile of the geocomposite needing repair. If the hole or tear width across the panel is more than 50 percent of the width of the panel, the damaged area will be cut out and the two portions of the geonet will be joined in accordance with this Section.

B. Any holes in the geonet will be repaired by placing a patch extending 2 ft beyond the edges of the hole. The patch will be secured every 6 inches with approved tying devices.

3.07 PLACEMENT OF OVERLYING MATERIALS

A. The Contractor will place all materials overlying the geonet and geocomposites in such a manner as to ensure that:
   1. the underlying geosynthetic materials are not damaged;
   2. minimal slippage occurs between these materials and the underlying layers; and
   3. excess stresses are not produced in the geonet and geocomposites.

B. The Contractor will spread soil on top of the geocomposites to cause the soil to cascade over the geocomposites rather than be shoved across the geocomposites.

C. Equipment will not be operated directly on the geonet and geocomposites. The Contractor will only operate equipment above the geonet and geocomposites that meets the following ground pressure requirements.

Allowable Equipment Ground Pressure (psi)	**Thickness of Overlying Soil (in.)**
<5	12
<10	18
<20	24
>20	36

3.08 PROTECTION OF WORK

A. The Contractor will use all means necessary to protect all prior work, including all materials and completed work of other Sections.

TABLE 02073-1
MATERIAL SPECIFICATIONS FOR GEONET AND GEOCOMPOSITES

PROPERTY	QUALIFIER	UNITS	SPECIFIED VALUES	TEST METHOD	MQC TESTING FREQUENCY
Geotextile Component of the Geocomposites					
Type			nonwoven		
Mass Per Unit Area	minimum	oz/yd^2	8	ASTM D5261	1 per 100,000 ft^2
Grab Tensile Strength	minimum	lbs	160	ASTM D4632	1 per 100,000 ft^2
Trapezoidal Tear Strength	minimum	lbs	60	ASTM D4533	1 per 100,000 ft^2
Puncture Strength	minimum	lbs	315	ASTM D6241	1 per 100,000 ft^2
Apparent Opening Size	maximum	inches	0.008	ASTM D4751	1 per 540,000 ft^2
Water Permeability	minimum	cm/s	0.1	ASTM D4491	1 per 540,000 ft^2
UV Resistance	minimum	percent	70	ASTM D4355	Per formulation
Physical/Mechanical Properties - Geonet (and Geonet Component of the Geocomposites)					
Polymer Composition	minimum	percent	95% polyethylene		
Thickness	minimum	inches	0.20	ASTM D5199	1 per 100,000 ft^2
Tensile Strength (MD)	minimum	lb/inch	40	ASTM D7179	1 per 100,000 ft^2
Carbon Black Content	minimum	%	2.0	ASTM D4218	1 per 100,000 ft^2
Density	minimum	g/cc	0.935	ASTM D792 or ASTM D1505	1 per 100,000 ft^2
Hydraulic Properties – Geonets and Geocomposites[3]					
LDS Geonet (floor) and Geocomposite (sideslope) Transmissivity	minimum	m^2/s	3.5×10^{-4}	ASTM D4716 per GRI GC 8, Part 6	Note 1
LCS Geocomposite Transmissivity	minimum	m^2/s	3.0×10^{-3}	ASTM D4716 per GRI GC 8, Part 6	Note 1
Final Cover Drainage Layer Geocomposite Transmissivity	minimum	m^2/s	5.3×10^{-4}	ASTM D4716 per GRI GC 8, Part 6	Note 2

Notes:

(1) Transmissivity refers to index transmissivity. LDS and LCS transmissivity tests to be performed between two steel plates at: applied stress of 2,000 psf (minimum); target gradient of 0.004 (minimum); and load duration of 15 minutes.

(2) Transmissivity refers to index transmissivity. Final cover drainage layer geocomposite transmissivity tests to be performed between two steel plates at: applied stress of 180 psf (minimum); target gradient of 0.03 (minimum); and load duration of 15 minutes.

(3) There is no hydraulic transmissivity specification for the final cover gas vent layer geocomposite.

[END OF SECTION]

SECTION 02075
GEOMEMBRANES

SECTION 02075

GEOMEMBRANES

PART 1 GENERAL

1.01 SECTION INCLUDES

A. A Geosynthetics Manufacturer will supply the 80-mil textured and smooth high density polyethylene (HDPE) geomembranes and 40-mil textured and smooth linear low density polyethylene (LLDPE) geomembranes.

B. The Contractor will furnish all labor, materials, supervision, and equipment to excavate the anchor trenches for the geomembranes and perform backfilling/compaction of fill in the anchor trenches. The Contractor will also furnish all labor, materials, tools, supervision, transportation, and equipment to install the geomembranes including, but not limited to layout, seaming, patching, and testing, and all necessary and incidental items required to complete the work in accordance with the Drawings and these Specifications.

1.02 RELATED SECTIONS

A. Section 02060 – Aggregates

B. Section 02071 – Geotextile

C. Section 02072 - Geosynthetic Clay Liner

D. Section 02073 - Geonet and Geocomposites

E. Section 02300 - General Earthwork

1.03 REFERENCES

A. Latest version of American Society for Testing and Materials (ASTM) Standards:

1. ASTM D792. Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement.
2. ASTM D1004. Standard Test Method for Tear Resistance (Graves Tear) of Plastic Film and Sheeting.
3. ASTM D1238. Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer.
4. ASTM D1505. Standard Test Method for Density of Plastics by Density-Gradient Technique.
5. ASTM D3895. Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry.

6. ASTM D4218. Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds By the Muffle-Furnace Technique.
7. ASTM D4833. Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products.
8. ASTM D4873. Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples.
9. ASTM D5321. Standard Test Method for Determining the Shear Strength of Soil-Geosynthetic and Geosynthetic-Geosynthetic Interfaces by Direct Shear.
10. ASTM D5323. Standard Practice for Determination of 2% Secant Modulus for Polyethylene Geomembranes.
11. ASTM D5397. Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test.
12. ASTM D5596. Standard Test Method of Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics.
13. ASTM D5617. Standard Test Method for Multi-Axial Tension Test for Geosynthetics.
14. ASTM D5641. Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber.
15. ASTM D5721. Standard Practice for Air-Oven Aging of Polyolefin Geomembranes.
16. ASTM D5820. Standard Practice for Pressurized Air Channel Evaluation of Duel Seamed Geomembranes.
17. ASTM D5885. Standard Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by High-Pressure Differential Scanning Calorimetry.
18. ASTM D5994. Standard Test Method for Measuring Core Thickness of Textured Geomembrane.
19. ASTM D6392. Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods.
20. ASTM D6693. Standard Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes.
21. ASTM D7238. Standard Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus.
22. ASTM D7466. Standard Test Method for Measuring the Asperity Height of Textured Geomembrane.

B. Geosynthetic Research Institute Standard Specification GM-10, Specification for the Stress Crack Resistance of HDPE Geomembrane Sheet.

C. Geosynthetic Research Institute Standard Specification GM-13, Standard Specification for Test Methods, Test Properties, and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes.

D. Geosynthetic Research Institute Standard Specification GM-17, Standard Specification for Test Methods, Test Properties and Testing Frequency for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes.

E. Geosynthetic Research Institute Standard Specification GM-19, Standard Specifications for Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes.

F. Daniel, D.E. and R.M. Koerner, 1993, Technical Guidance Document: Quality Assurance and Quality Control for Waste Containment Facilities, EPA/600/R-93/182.

G. Construction Quality Assurance (CQA) Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. The installation of the geomembrane will be monitored as outlined in the CQA Plan.

B. The Contractor will be aware of the activities set forth in the CQA Plan and will account for these activities in the construction schedule.

1.05 WARRANTY

A. The Geosynthetics Manufacturer will furnish a 20-year written Manufacturer's warranty against defects in materials.

1.06 QUALIFICATIONS

A. Geosynthetics Manufacturer
   1. The Geosynthetics Manufacturer will be responsible for the production and delivery of geomembrane rolls and will be a well-established firm with more than one year of experience in the manufacture of similar geomembrane products. The Manufacturer will submit a statement listing:
      a. Certified minimum property values of the proposed geomembranes and the tests used to determine those properties.
      b. Production capacity available and project delivery dates for this project.

B. Contractor
   1. The Contractor will be responsible for field handling, storing, deploying, seaming or joining, temporary retraining (against wind), anchoring systems, and other site aspects of the geomembranes.
   2. The Contractor will be trained and qualified to install similar geomembrane products.

C. The Geosynthetics Manufacturer and Contractor will accept and retain full responsibility for all materials and installation and will be held responsible for any defects in the completed system.

PART 2 PRODUCTS

2.01 MATERIALS

A. The LLDPE geomembrane resin properties will meet the requirements set forth in the GRI Test Method GM-17, including a resin density generally in the range of 0.926 g/cc or lower (ASTM D792 or ASTM D1505) and a melt flow index of less than 1.0 g/10 min (ASTM D1238).

B. The HDPE geomembrane resin properties will meet the requirements set forth in the GRI Test Method GM-13, including a resin density generally in the range of 0.932 g/cc or higher (ASTM D792 or ASTM D1505) and a melt flow index of less than 1.0 g/10 min (ASTM D1238).

C. Material requirements for the 40-mil smooth LLDPE, 40-mil textured LLDPE, 80-mil smooth HDPE, and 80-mil textured HDPE geomembranes are presented in Tables 02075-1, 02075-2, 02075-3, and 02075-4, respectively.

D. The method and degree of texturing will be approved by the CQA Certifying Engineer. The texturing will have a uniform appearance, be consistent among rolls, and be consistent with the approved samples.

E. Geomembranes will be shipped rolled.

F. No reclaimed material (that is, material that has seen previous service) will be allowed in the geomembrane.

G. Up to 10 percent by weight of clean, uncontaminated regrind material (i.e., material that has been previously processed by the same manufacturer, but has never seen previous service) will be allowed in the geomembrane sheet if pre-approved by the MCP or their designated representatives. Approval will not be unreasonably withheld if the manufacturer can demonstrate compliance with this Section. Regrind material made of the same resin as the geomembrane liner from a sheet failing the physical properties of the liner or resin will not be allowed under any circumstances. Edge trim and sheet failed for thickness or cosmetic reasons may be considered for regrind.

H. The geomembranes will be free of pinholes and reasonably free from surface blemishes, scratches, and other defects.

I. The anchor trenches will be backfilled by the Contractor with structural fill meeting the requirements of Section 02300 and as shown on the Drawings.

2.02 MANUFACTURING QUALITY CONTROL

A. The geomembranes will be manufactured with quality control procedures that meet generally accepted industry standards.

B. The Geosynthetics Manufacturer will sample and test the geomembranes to demonstrate that the material conforms to the requirements of this Section and values specified in Tables 02075-1 through 02075-4.

C. The Geosynthetics Manufacturer will submit quality control certificates signed by the Geosynthetics Manufacturer quality control manager. The quality control certificates will include:
   1. lot, batch, and roll number and identification; and
   2. results of manufacturing quality control tests including description of test methods used.

D. Any geomembrane sample that does not comply with this Section will result in rejection of the roll from which the sample was obtained. The Geosynthetics Manufacturer will replace any rejected rolls at no additional cost.

E. If a geomembrane sample fails to meet the quality control requirements of this Section, the Geosynthetics Manufacturer will sample and test each roll manufactured in the same lot or batch, or at the same time, as the failing roll. Sampling and testing of rolls will continue until a pattern of acceptable test results is established.

F. Additional sample testing may be performed, at the Geosynthetics Manufacturer's discretion and expense, to more closely identify any non-complying rolls and/or to qualify individual rolls.

G. Sampling will, in general, be performed on sacrificial portions of the geomembrane material such that repair is not required. The Geosynthetics Manufacturer will sample and test the geomembrane at the frequencies presented in these Specifications and ensure that its properties conform to the specified values.

2.03 PACKAGING AND LABELING

A. Geomembranes will be supplied in rolls wrapped in weather-resistant, opaque and relatively impermeable protective covers. Wrapping which becomes torn or damaged will be repaired with similar materials.

B. Geomembrane rolls will be labeled consistent with ASTM D 4873, with the following information:
   1. manufacturer's name;
   2. product identification;
   3. lot or batch number;
   4. roll number; and
   5. roll dimensions.

C. Geomembrane rolls, which cannot be identified per above because of missing, illegible, or damaged labels, will be rejected, removed from the jobsite, and replaced with properly labeled rolls at no additional cost.

2.04 TRANSPORTATION

A. Transportation of the geomembranes will be the responsibility of the Geosynthetics Manufacturer. The Geosynthetics Manufacturer will be liable for all damages to the materials incurred prior to and during transportation to the site.

B. Geomembranes will be delivered to the site at least 14 days prior to the planned deployment date to allow adequate time to perform conformance testing on the geomembrane samples as required by the CQA Plan.

2.05 HANDLING AND STORAGE

A. The Contractor will be responsible for unloading the geomembrane rolls delivered to the site, and for placing them in the designed storage area.

B. Once the geomembranes are unloaded at the site and placed in the designated storage area, the Contractor will be responsible for all additional unloading, handling, storage and care at the site. The geomembranes will be stored off the ground and out of direct sunlight, and will be protected from excessive heat or cold, mud, dirt, and dust or other damaging or deleterious conditions. Any additional storage procedures required by the Geosynthetics Manufacturer will be the Contractor's responsibility.

PART 3 EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any of the work in this Section, the Contractor will carefully inspect the installed work of all other Sections and verify that all work is complete to the point where the work of this Section may properly commence without adverse impact.

3.02 CONFORMANCE TESTING

A. Conformance sampling and testing requirements for the geomembranes are presented in Table 02075-6.

B. Conformance testing will be performed by an independent, third-party laboratory. Conformance sampling may be performed either at the manufacturing plant or upon delivery of rolls to the site. Conformance samples will be taken across the entire roll width. All conformance test results will be reviewed by the onsite QA/QC Manager prior to deployment of the material. When a sample fails a conformance test, the material from the lot represented by the failing test should be considered out-of-specification and rejected.

C. Additional conformance samples may be taken to isolate the portion of the lot not meeting the specifications. To isolate the out-of-specification material, two additional conformance samples should be taken from the closest numerical roll numbers to the failing sample. If both samples pass, only the initial failed roll will be rejected. If any one of the additional tests fails, then the entire lot will be rejected and the procedure may be repeated with additional tests to further bracket the failing rolls within the lot.

3.03 HANDLING AND PLACEMENT

A. The Contractor will not commence geomembrane installation until the onsite QA/QC Manager completes conformance evaluation of the geomembranes and quality assurance evaluation of previous work, including evaluation of survey results for previous work.

B. The Contractor will handle all geomembranes in such a manner as to ensure the geomembranes are not damaged in any way.

C. The Contractor will take any necessary precautions to prevent damage to underlying layers including rutting during placement of the geomembranes.

D. In the presence of wind, all geomembranes will be weighted by the Contractor with sandbags or the equivalent. Such sandbags will be installed during placement and will remain until the overlying layer is placed.

E. Seams should be oriented parallel to the line of maximum slope, i.e., oriented up and down, not across, the slope. In corners and odd shaped geometric locations, the number of field seams should be minimized.

F. On side slopes where applicable, the geomembranes will be temporarily secured in the anchor trench and then rolled down the slope in such a manner as to continually keep the geomembranes in tension (i.e., no slack).

G. If necessary, the geomembranes will be positioned by hand after being unrolled to minimize wrinkles.

H. Geomembranes will only be cut using Manufacturer’s recommended procedures.

I. Tools will not be left on, in, or under the geomembranes.

3.04 SURFACE PREPARATION

A. No geomembrane will be placed onto an area with an excessively soft subgrade (e.g., softened by precipitation, excessively hydrated GCL, etc.).

B. Any damage to the underlying subgrade caused by geomembrane installation activities (e.g., wheel ruts from ATVs, etc.) will be repaired.

C. The Contractor will excavate the geomembrane anchor trenches as shown on the drawings.

3.05 GEOMEMBRANE INSTALLATION

A. Surfaces to receive geomembrane installation will be relatively smooth, even, and free of ruts, voids, protrusions, deleterious material, and excess moisture. Vehicles leaking contaminants or causing ruts, pumping, or deformation of the underlying surface greater than 1 inch or otherwise unacceptable are not permitted. Any damage to the surface caused by the Contractor's vehicles will be repaired.

B. Anchor trenches will be required at the crest of the cell side slope at the locations shown on the Drawings to secure the geomembranes. The Contractor will take precautions to minimize loose soil underlying the geomembranes in the anchor trenches.

C. Installation of the Geomembranes will be as follows:
   1. Only those panels which are to be seamed together or anchored in one day will be unrolled. Panels should be positioned with the overlap recommended by the manufacturer, but not less than 3 inches, after the necessary alignment and cutting. The edge of the upslope sheet will be positioned above the edge of the downslope sheet in a shingle-like fashion.
   2. The geomembrane panels on the side slope will be placed in the anchor trenches at the top and toe of the slope. The anchor trenches will then be backfilled by the Contractor with compacted soil as shown on the Drawings.
   3. After panels are initially in place, geomembranes will be allowed to "relax" and wrinkles will be removed to the extent possible. The purpose of this is to make the edges which are to be bonded as smooth and free of wrinkles as possible.
   4. Once panels are in place and smooth, field seaming operations will commence.
   5. At the end of each day or installation segment, all unseamed edges will be anchored by the Contractor using rope, sand bags, or other approved device. Sand bags securing the geomembranes on the side slopes should be connected by rope fastened at the top of the slope section by a temporary anchor. Staples, U-shaped rods or other penetrating anchors will not be used to secure the geomembranes. Any damage to the liner due to wind, rain, hail, or other weather will be the sole responsibility of the Contractor.

D. Field seaming may be extrusion or fusion welding or a combination of these methods, unless noted otherwise on the Drawings. Solvent welding is not acceptable. Additional concepts and requirements of proper field seaming include the following:
   1. All foreign matter (dirt, water, oil, etc.) will be removed from the edges to be bonded. For extrusion-type welds, the bonding surfaces must be thoroughly cleaned by mechanical abrasion or alternate methods approved by the onsite QA/QC Manager to remove surface oxidation and prepare the surfaces for bonding. All abrasive buffing will be performed using No. 90 grit or finer sandpaper. The grinding will be performed so that grind marks are generally

perpendicular to the edge of sheet. No solvents will be used to clean the geomembranes.

2. As much as practical, field seaming will start from the top of the slope down. Tack welds (if used) will use heat only; no double sided tape, glue or other method will be permitted.
3. The completed liner will not exhibit any "trampolining" at the time protective cover or other materials are being placed over the geomembranes.
4. No horizontal seams should be within 5 feet of the toe of slopes.
5. No seaming should be attempted above 104°F ambient air temperature. Preheating of the geomembranes will be required below 41°F, unless it is demonstrated that this is not necessary (i.e., acceptable trial test (start-up) seams which duplicate, as closely as possible, actual field conditions). Preheating may be achieved by natural and/or artificial means (shelters and heating devices). Ambient air temperature will be measured 6 inches above the geomembrane liner surface.
6. A moveable protective layer of plastic may be required, as recommended by the onsite QA/QC Manager, to be placed directly below each overlap of geomembrane that is to be seamed, to prevent moisture build-up between the sheets to be welded.
7. Seaming will extend to the outside edge of panels to be placed in anchor trenches.
8. If required, a firm working surface should be provided by using a flat board or similar hard surface directly under the seam overlap to achieve proper support. The working surface must be removed after seaming is complete.
9. No excessive grinding prior to welding will be permitted. Overly ground or improperly ground areas will be replaced at the Contractor's expense.
10. Seams at panel intersections of 3 or 4 sheets will be completed with a patch having a minimum dimension of 24 inches, extrusion welded to the parent sheets. Open ends of all air channels must be welded closed.

3.06 GEOMEMBRANE TESTING

A. All geomembrane sheets and seams will be tested and evaluated prior to acceptance. In general, testing of the sheets will be conducted by the Geosynthetics Manufacturer. Testing of the seams will be conducted by the Contractor under observation by the onsite QA/QC Manager. The QA/QC Manager or a designated, independent geosynthetics laboratory will perform additional testing, as required by these detailed Specifications, the CQA Plan, or as required in the judgment of the QA/QC Manager to verify that the geomembrane sheets and seams meet the specifications. Field testing requirements are detailed in the following subsections.

1. Trial Test Seams: The Contractor will maintain and use equipment and personnel at the site to perform testing of trial test seams. Test seams will be made each day prior to commencing field seaming. These seams will be made on fragment pieces of geomembrane liner to verify that seaming conditions are adequate. Such test seams will be made at the beginning of each seaming period, at the QA/QC Manager's discretion, and at least once every four hours during

continuous operation of each welding machine. Also, each seamer will make at least one test seam each day. Requirements for test seams are as follows:

a. The test seam sample will be at least 3 feet long by 1 foot wide with the seam centered lengthwise. Six adjoining specimens 1 inch wide each will be die cut from the test seam sample. These specimens will be tested in the field with a tensiometer for both shear (3 specimens) and peel (3 specimens). Test seams will be tested by the Contractor under observation of the QA/QC Manager. The specimens should not fail in the weld. The Contractor will supply all necessary knowledgeable personnel and testing equipment. No strain measurements need be obtained in the field.

b. A passing fusion or extrusion welded test seam will be achieved when the criteria described in Table 02775-6 are satisfied with the exclusion of any strain requirements. If a test seam fails, the entire operation will be repeated. If the additional test seam fails, the seaming apparatus or seamer will not be accepted and will not be used for seaming until the deficiencies are corrected and two consecutive successful full test seams are achieved. Test seam failure is defined as failure of any one of the specimens tested in shear or peel. For double-weld seams, both welds will meet the test seam criteria.

2. Non-Destructive Testing: Production seams will be tested by the Contractor continuously using non-destructive techniques. The Contractor will perform all pressure and vacuum testing under the observation of the QA/QC Manager. Requirements for non-destructive testing are as follows:

   a. Single Weld Seams - The Contractor will maintain and use equipment and personnel at the site to perform continuous vacuum box testing on all single weld production seams. The system will be capable of applying a vacuum of at least 3 psi. The vacuum will be held for a minimum of 15 seconds for each section of seam.

   b. Double Weld Seams - The Contractor will maintain and use equipment and personnel to perform air pressure testing of all double weld seams. The system will be capable of applying a pressure of at least 30 psi for not less than 5 minutes. Pressure loss tests will be conducted in accordance with the procedures outlined in "Pressurized Air Channel Test for dual Seamed Geomembranes," Geosynthetic Research Institute Test Method GM-6. As outlined by the test method, following a 2 minute pressurized stabilization period pressure losses over a measurement period of 5 minutes will not exceed 4 psi.

   c. Any seam that cannot be nondestructively tested will be capped.

3. Destructive Testing: Destructive testing of production seams will be performed on samples collected from selected locations to evaluate seam strength and integrity according to the requirements presented in Table 02075-6. Destructive testing will be carried out as the geomembrane installation progresses, not at the completion of all field seaming. Field seam samples will be collected for destructive testing at a minimum average frequency of one test location per 500 ft of seam length per seamer/welder combination. The QA/QC Manager will be responsible for choosing the test sample locations and may increase the sampling

frequency. The sampling, field testing, and laboratory testing procedures described in the CQA Plan will be followed. Samples that do not pass the shear and peel tests will be re-sampled from locations at least 10 feet on each side of the original location. These two re-test samples must pass both shear and peel testing. If these two samples do not pass, then additional samples will continue to be obtained until the questionable seam area is defined. Once the limits of the failed seam have been defined, the Contractor will reconstruct the seam.

3.07 REPAIR OF DAMAGED AND SAMPLED AREAS

A. Damaged and sample coupon areas of geomembrane will be repaired by the Contractor by construction of a cap strip. No repairs will be made to seams by application of an extrusion bead to a seam edge previously welded by fusion or extrusion methods. Repaired areas will be tested for seam integrity. Damaged materials are the property of the Contractor and will be removed from the site.

3.08 POTENTIALLY DAMAGING ACTIVITIES

A. No support equipment used by the Contractor will be allowed on the geomembranes unless the equipment and protective measures are approved by the QA/QC Manager. Light-weight portable generators must be placed on protective rub sheets, and stands or supports will be adequately padded to prevent potential damage to the rub sheet or geomembrane. All-terrain-vehicles (ATVs) may only be operated on the geomembranes if deemed necessary by the QA/QC Manager. If used, an ATV will have sufficiently low tire pressure to prevent damage to the geomembranes. Wheels of ATVs must be thoroughly cleaned to remove stones and other deleterious material prior to operation on the geomembranes. Personnel working on the geomembranes will not smoke, wear damaging shoes, or engage in any activity which damages the geomembranes.

3.09 ANCHOR TRENCH BACKFILLING

A. The anchor trenches will be backfilled and compacted by the Contractor in accordance with the requirements of Section 02300.

B. The Contractor will take precautions to prevent damage to the geomembrane during backfilling of anchor trenches. Only equipment or vehicles meeting the following ground pressure requirements in the table below, with the corresponding minimum thickness of soil overlying the geomembranes, will be used to haul and compact structural fill in the anchor trenches.

Allowable Equipment Ground Pressure (psi)	Minimum Thickness of Soil Overlying Geosynthetics (in.)
<5	12
<10	18
<20	24
>20	36

3.10 GEOMEMBRANE ACCEPTANCE

A. The Contractor will retain all ownership and responsibility for the geomembranes until accepted by the MCP or their designated representatives.

B. The geomembranes will be accepted by the MCP or their designated representatives when:
   1. the installation is finished;
   2. all documentation of installation is completed including the QA/QC Manager's final report; and
   3. verification of the adequacy of all field seams and repairs, including associated testing, is complete.

3.11 PROTECTION OF WORK

A. The Contractor will use all means necessary to protect all prior work, including all materials and completed work of other Sections.

TABLE 02075-1
MATERIAL SPECIFICATIONS
40-mil LINEAR LOW DENSITY POLYETHYLENE (LLDPE) GEOMEMBRANE – SMOOTH

PROPERTY	QUALIFIER	UNITS	SPECIFIED VALUES	TEST METHOD	MQC TESTING FREQUENCY (Minimum)
Thickness: Nominal	min. avg.	mil	40[(1)]	ASTM D5199	per roll
lowest individual of 10 values		mil	36		
Density	maximum	g/cc	0.939	ASTM D1505 ASTM D792	200,000 lb
Tensile Properties (each direction)	min. avg.			ASTM D6693 Type IV	20,000 lb
Break Strength		lb/in.	152		
Break Elongation		percent	800		
2% Modulus	maximum	lb/in.	2,400	ASTM D5323	per formulation
Tear Resistance	min. avg.	lb	22	ASTM D1004	45,000 lb
Puncture Resistance	min. avg.	lb	56	ASTM D4833	45,000 lb
Axi-Symmetric Break Resistance Strain	minimum	percent	30	ASTM D5617	per formulation
Carbon Black Content	range	percent	2.0 to 3.0	ASTM D4218[(2)]	20,000 lb
Carbon Black Dispersion		cat.	note[(3)]	ASTM D5596	45,000 lb
Oxidative Induction Time (OIT)	min. avg.				200,000 lb
Standard OIT; or		minutes	100	ASTM D3895	
High Pressure OIT		minutes	400	ASTM D5885	
Oven Aging at 85°C and 90 days	min. avg.			ASTM D5721	per formulation
Standard OIT; or		% ret.	35	ASTM D3895	
High Pressure OIT		% ret.	60	ASTM D5885	
UV Resistance at cycle of 20 hr UV at 75°C then 4 hr condensation at 60°C	min. avg.	% ret.	35	ASTM D5885	per formulation
High Pressure OIT at 1600 hrs					

Notes:

(1) The average of the 10 readings shall meet or exceed the nominal specified thickness of 40 mils.

(2) Other methods such as D1603 (tube furnace) or D6370 (TGA) are acceptable if an appropriate correlation to D4218 (muffle furnace) can be established.

(3) Carbon black dispersion (only near spherical agglomerates) for 10 different views shall have 9 in Categories 1 or 2 and 1 in Category 3.

(4) This specification is based on the Geosynthetic Research Institute (GRI) GM-17 Specification, currently the industry standard. Specified test methods and parameters may be modified by the Design Engineer to be consistent with changes to the industry standard for 40 mil smooth LLDPE geomembranes.

TABLE 02075-2
MATERIAL SPECIFICATIONS
40-mil LINEAR LOW DENSITY POLYETHYLENE (LLDPE) GEOMEMBRANE – TEXTURED

PROPERTY	QUALIFIER	UNITS	SPECIFIED VALUES	TEST METHOD	MQC TESTING FREQUENCY (Minimum)
Thickness: Nominal	min. avg.	mil	40(1)	ASTM D5994	per roll
8 out of 10 values must exceed		mil	36		
all 10 values must exceed		mil	34		
Asperity Height(2)	min. avg.	mil	10	ASTM D7466	every 2nd roll(3)
Density	maximum	g/cc	0.939	ASTM D1505 ASTM D792	200,000 lb
Tensile Properties (each direction)	min. avg.			ASTM D6693 Type IV	20,000 lb
Break Strength		lb/in.	60		
Break Elongation		percent	250		
2% Modulus	maximum	lb/in.	2400	ASTM D5323	per formulation
Tear Resistance	min. avg.	lb	22	ASTM D1004	45,000 lb
Puncture Resistance	min. avg.	lb	44	ASTM D4833	45,000 lb
Axi-Symmetric Break Resistance Strain	minimum	percent	30	ASTM D5617	per formulation
Carbon Black Content	range	percent	2.0 to 3.0	ASTM D4218(4)	20,000 lb
Carbon Black Dispersion		cat.	note(5)	ASTM D5596	45,000 lb
Oxidative Induction Time (OIT)	min. avg.				200,000 lb
Standard OIT; or		minutes	100	ASTM D3895	
High Pressure OIT		minutes	400	ASTM D5885	
Oven Aging at 85°C and 90 days	min. avg.			ASTM D5721	per formulation
Standard OIT; or		% ret.	35	ASTM D3895	
High Pressure OIT		% ret.	60	ASTM D5885	
UV Resistance at cycle of 20 hr UV at 75°C then 4 hr condensation at 60°C	min. avg.	% ret.	35	ASTM D5885	per formulation
High Pressure OIT at 1600 hrs					

Notes:

(1) The average of the 10 readings shall meet or exceed the nominal specified thickness of 40 mils.

(2) Of 10 readings, 8 of 10 must be ≥ 7 mils and lowest individual reading must be ≥ 5 mils.

(3) Alternate the measurement side for double-sided textured sheet.

(4) Other methods such as D1603 (tube furnace) or D6370 (TGA) are acceptable if an appropriate correlation to D4218 (muffle furnace) can be established.

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views shall have 9 in Categories 1 or 2 and 1 in Category 3.

(6) This specification is based on the Geosynthetic Research Institute (GRI) GM-17 Specification, currently the industry standard. Specified test methods and parameters may be modified by the Design Engineer to be consistent with changes to the industry standard for 40 mil textured LLDPE geomembranes.

TABLE 02075-3
MATERIAL SPECIFICATIONS
80-mil HIGH DENSITY POLYETHYLENE (HDPE) GEOMEMBRANE – SMOOTH

PROPERTY	QUALIFIER	UNITS	SPECIFIED VALUES	TEST METHOD	MQC TESTING FREQUENCY (Minimum)
Thickness: Nominal	min. avg.	mil	80[1]	ASTM D5199	per roll
lowest individual of 10 values		mil	72		
Density	minimum	g/cc	0.940	ASTM D1505/ D792	200,000 lb
Tensile Properties (each direction)				ASTM D6693 Type IV	20,000 lb
1. Tensile Strength at Yield	min. avg.	lb/in.	168		
2. Tensile Strength at Break	min. avg.	lb/in.	304		
3. Elongation at Yield	min. avg.	percent	12		
4. Elongation at Break	min. avg.	percent	700		
Tear Resistance	min. avg.	lb	56	ASTM D1004	45,000 lb
Puncture Resistance	min. avg.	lb	144	ASTM D4833	45,000 lb
Stress Crack Resistance[2]	minimum	hours	300	ASTM D5397	per GRI GM-10
Carbon Black Content	range	percent	2.0 to 3.0	ASTM D4218[3]	20,000 lb
Carbon Black Dispersion		cat.	note[4]	ASTM D5596	45,000 lb
Oxidative Induction Time (OIT)					200,000 lb
1. Standard OIT; or	min. avg.	minutes	100	ASTM D3895	
2. High Pressure OIT	min. avg.	minutes	400	ASTM D5885	
Oven Aging at 85°C and 90 days				ASTM D5721	per formulation
1. Standard OIT; or	min. avg.	% ret.	55	ASTM D3895	
2. High Pressure OIT	min. avg.	% ret.	80	ASTM D5885	
UV Resistance at 20 hr UV at 75°C then 4 hr condensation at 60°C				ASTM D7238	per formulation
1. High Pressure OIT at 1600 hrs	min. avg.	% ret.	50	ASTM D5885	
Interface Shear Strength (smooth geomembrane to geosynthetic clay liner (GCL))	minimum	degrees	Failure Envelope[5]	ASTM D5321	Note 5
Interface Shear Strength (smooth geomembrane to geonet)	minimum	degrees	Failure Envelope[5]	ASTM D5321	Note 5

Notes:

(1) The average of the 10 readings will meet or exceed the nominal specified thickness of 80 mils.

(2) Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation.

(3) Other methods such as D1603 (tube furnace) or D6370 (TGA) are acceptable if an appropriate correlation to D4218 (muffle furnace) can be established.

(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views will have 9 in Categories 1 or 2 and 1 in Category 3.

(5) Interface shear strength testing will be performed by a qualified, independent third-party geosynthetics testing laboratory prior to shipping. Each geosynthetic interface that will be in contact with the geomembrane will be tested (e.g., GM-GCL interface; GM-geonet interface) as specified in the table above. Each interface will have effective-stress interface strengths that meet or exceed the following:

e	Interface Shear Strength (degrees)	
	Peak	Large-Displacement
120	8.3	3.6
1,800	8.6	4.8

Interface shear tests will be performed at the normal stresses indicated above, using fresh specimens for each test configuration. The adjacent interface may be tested in one test configuration (e.g., geonet to geomembrane to GCL). The GCL will be tested in a hydrated condition. The GCL will be hydrated at low stress, and then consolidated for a 24-48 hours before shearing.

Passing interface strength results for a particular interface are applicable from project-to-project at the site (e.g., for subsequent subcell/phase construction, etc.) and testing need not be repeated, provided that the geosynthetic type and soil source/properties proposed for use remains representative of those tested.

(6) This specification is based on the Geosynthetic Research Institute (GRI) GM-13 Specification, currently the industry standard. Specified test methods and parameters may be modified by the Design Engineer to be consistent with changes to the industry standard for 80 mil smooth HDPE geomembranes.

TABLE 02075-4
MATERIAL SPECIFICATIONS
80-mil HIGH DENSITY POLYETHYLENE (HDPE) GEOMEMBRANE – TEXTURED

PROPERTY	QUALIFIER	UNITS	SPECIFIED VALUES	TEST METHOD	MQC TESTING FREQUENCY (Minimum)
Thickness: Nominal	min. avg.	mil	80(1)	ASTM D5994	per roll
8 out of 10 values must exceed		mil	72		
all 10 values must exceed		mil	68		
Asperity Height(2)	min. avg.	mil	10	ASTM D7466	every 2nd roll
Density	minimum	g/cc	0.940	ASTM D1505/ D792	200,000 lb
Tensile Properties (each direction)				ASTM D6693 Type IV	20,000 lb
1. Tensile Strength at Yield	min. avg.	lb/in.	168		
2. Tensile Strength at Break	min. avg.	lb/in.	120		
3. Elongation at Yield	min. avg.	percent	12		
4. Elongation at Break	min. avg.	percent	100		
Tear Resistance	min. avg.	lb	56	ASTM D1004	45,000 lb
Puncture Resistance	min. avg.	lb	120	ASTM D4833	45,000 lb
Stress Crack Resistance(3)	minimum	hours	300	ASTM D5397	per GRI GM-10
Carbon Black Content	range	percent	2.0 to 3.0	ASTM D4218(4)	20,000 lb
Carbon Black Dispersion		cat.	note(5)	ASTM D5596	45,000 lb
Oxidative Induction Time (OIT)					200,000 lb
1. Standard OIT; or	min. avg.	minutes	100	ASTM D3895	
2. High Pressure OIT	min. avg.	minutes	400	ASTM D5885	
Oven Aging at 85°C and 90 days				ASTM D5721	per formulation
1. Standard OIT; or	min. avg.	% ret.	55	ASTM D3895	
2. High Pressure OIT	min. avg.	% ret.	80	ASTM D5885	
UV Resistance at 20 hr UV at 75°C then 4 hr condensation at 60°C				ASTM D7238	per formulation
1. High Pressure OIT at 1600 hrs	min. avg.	% ret.	50	ASTM D5885	
Interface Shear Strength (textured geomembrane to geosynthetic clay liner (GCL))	minimum	degrees	Failure Envelope(6)	ASTM D5321	Note 6
Interface Shear Strength (textured geomembrane to double-sided geocomposite)	minimum	degrees	Failure Envelope(6)	ASTM D5321	Note 6

Notes:

(1) The average of the 10 readings will meet or exceed the nominal specified thickness of 80 mils.

(2) Of 10 readings, 8 of 10 must be ≥ 7 mils and lowest individual reading must be ≥ 5 mils.

(3) Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation.

(4) Other methods such as D1603 (tube furnace) or D6370 (TGA) are acceptable if an appropriate correlation to D4218 (muffle furnace) can be established.

TABLE 02075-4
MATERIAL SPECIFICATIONS
80-mil HIGH DENSITY POLYETHYLENE (HDPE) GEOMEMBRANE – TEXTURED

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views will have 9 in Categories 1 or 2 and 1 in Category 3.

(6) Interface shear strength testing will be performed by a qualified, independent third-party geosynthetics testing laboratory prior to shipping. Each geosynthetic interface that will be in contact with the geomembrane will be tested (e.g., GM-GCL interface; GM-double-sided geocomposite interface) as specified in the table above. Each interface will have effective-stress interface strengths that meet or exceed the following:

Normal Stress (psf)	Interface Shear Strength (degrees)	
	Peak	Large-Displacement
120	8.3	3.6
1,800	8.6	4.8

Interface shear tests will be performed at the normal stresses indicated above, using fresh specimens for each test configuration. The adjacent interface may be tested in one test configuration (e.g., double-sided geocomposite to geomembrane to GCL). The GCL will be tested in a hydrated condition. The GCL will be hydrated at low stress, and then consolidated for a 24-48 hours before shearing.

Passing interface strength results for a particular interface are applicable from project-to-project at the site (e.g., for subsequent subcell/phase construction, etc.) and testing need not be repeated, provided that the geosynthetic type and soil source/properties proposed for use remains representative of those tested.

(7) This specification is based on the Geosynthetic Research Institute (GRI) GM-13 Specification, currently the industry standard. Specified test methods and parameters may be modified by the Design Engineer to be consistent with changes to the industry standard for 80 mil smooth HDPE geomembranes.

TABLE 02075-5
CQA CONFORMANCE TESTING REQUIREMENTS FOR GEOMEMBRANES

TEST	METHOD	MINIMUM FREQUENCY OF CQA TESTING[1]
Thickness – Lab Measurement[2]	ASTM D5199 or D5994	1 per 100,000 ft^2
Sheet Density	ASTM D1505/D792	1 per 100,000 ft^2
Tensile Properties	ASTM D6693 Type IV	1 per 100,000 ft^2
Carbon Black Content	ASTM D 4218	1 per 100,000 ft^2
Carbon Black Dispersion	ASTM D 5596	1 per 100,000 ft^2
Interface Shear Strength	ASTM D 5321	1 per interface specified in Tables 02075-3 and 02075-4[3]

Notes:
(1) CQA testing frequency will also be at a minimum of one per resin lot.
(2) Thickness of smooth geomembranes will be measured in accordance with ASTM D5199. Thickness of textured geomembranes will be measured in accordance with ASTM D5994.
(3) See Tables 02075-3 and 02075-4 for information on testing conditions.
(4) Specified test methods and parameters may be replaced by Design Engineer to be consistent with the industry standard for geomembranes.

TABLE 02075-6
WELDED SEAM SPECIFICATIONS FOR GEOMEMBRANES

PROPERTY	QUALIFIER	UNITS	VALUES[1, 2]		TEST METHOD[3]	CQA TESTING FREQUENCY
			40 mil LLDPE (smooth and textured)	80 mil HDPE (smooth and textured)		
Fusion Seams						
Air Test	-	psi	30 psi pressure, 5 minute hold, pressure must not drop by 3 psi		ASTM D5820	Observe Installer testing 100% of fusion seams
Shear Strength	Minimum	lb/in.	60	160	GRI GM-19 (using ASTM D6392)	(4) and (5)
Shear Elongation at Break	Minimum	%	50	50		
Peel Strength	Minimum	lb/in.	50	121		
Peel Separation	Minimum	%	25	25		
Extrusion Seams						
Vacuum Test	-	psi	5 psi vacuum, 10 second hold		ASTM D5641	Observe Installer testing 100% of extrusion seams
Shear Strength	Minimum	lb/in.	60	160	GRI GM-19 (using ASTM D6392)	(4) and (5)
Shear Elongation at Break	Minimum	%	50	50		
Peel Strength	Minimum	lb/in.	44	104		
Peel Separation	Minimum	%	25	25		

Notes:

(1) For all destructive tests, 4 of 5 samples must meet or exceed the above values, and all samples must meet or exceed 80% of the above values for a test to pass.

(2) Locus-of-break patterns will meet the acceptable break codes given in GRI GM-19. The following are patterns are unacceptable break codes: fusion – AD, AD-Brk >25%; extrusion – AD1, AD2, AD-WLD (if strength is not achieved)

(3) This specification is based on the Geosynthetic Research Institute (GRI) GM-19 Specification, currently the industry standard for welded geomembrane seams. Specified test methods and parameters may be modified by the Design Engineer to be consistent with changes to the industry standard for geomembrane seams.

(4) Trial seams will be made by the Installer (and observed/documented by CQA personnel) at start of each day and at re-start after breaks, shift change, etc. Elongation/separation measurements may be eliminated for field testing.

(5) Destructive tests will be taken at a minimum frequency of one per 500 linear feet of welded production seam.

[END OF SECTION]

SECTION 02210
SLUDGE SOLIDIFICATION

SECTION 02210
SLUDGE SOLIDIFICATION

PART 1 GENERAL

1.1 DESCRIPTION OF WORK

A. This section includes the minimum requirements for sludge solidification and related work as indicated on the drawings and as specified herein to complete the solidification of sludge. The work consists of furnishing all labor, equipment, and materials and performing all operations as required to complete the solidification of sludge as detailed in the Record of Decision (ROD).

1.2 RELATED SECTIONS

A. Section 01300 – Submittals
B. Section 02025 – Air Monitoring
C. Section 02055 – Decontamination/Dismantling of Tanks and Process Equipment
D. Section 02085 – Monitoring Well Abandonment
E. Section 02200 – Solidification Field Pilot Study
F. Section 02500 – Surveying

1.3 DEFINITIONS

A. Acceptable Solidification Performance Criteria – Obtaining a minimum unconfined compressive strength of 15 psi while expressing no free moisture.
B. Admixture – Materials such as quicklime, fly ash, and Portland cement,
C. Contaminated Soils – Soils within the designated soil remediation areas or visual
D. Reagent – the material or mixture of materials mixed with the untreated sludge in order to obtain a minimum UCS value with no free moisture being expressed
E. Sludge – Materials referred to as sludge at the Malone Service Company Superfund Site consisting of the petroleum hydrocarbon semi-solids resting within the inside the sludge pit, oil pit, API separators, and numerous storage tanks.
F. TS – Treatability Study
G. UCS – unconfined compressive strength

1.4 TREATABILITY/PILOT STUDIES

A. August 2006 TS by URS

B. February 2008 Stabilization/Solidification TS by Shaw Technology Applications Laboratory

C. October 2013 Solidification TS by ENTACT – As part of the Phase One RD, ENTACT collected additional samples and conducted another solidification Treatability Study to confirm the results of previous studies and to identify the most efficient reagent blend available at the present time which will deliver the minimum passing values for the treated SS materials.

D. July 2014 Full-Scale Solidification Pilot Study – As part of the Phase One RA, ENTACT completed a full-scale pilot study to show that the bench scale treatability study mix designs can be effectively performed in the field utilizing the same type of equipment and methodologies intended for use during site solidification activities.

PART 2 PRODUCTS

2.1 REAGENTS

A. Reagents include on-site soil, Calcium Oxide (CaO) or quicklime, Portland cement (PC), and fly ash, which will be mixed with the sludges and contaminated soils in sufficient ratios to deliver the resulting UCS values of the solidified sludge materials in accordance with these specifications

a. Cement: Cement will conform to ASTM C-150 Standard Specification for Portland cement and will meet the ASTM requirements for Type I-II. The cement will be adequately protected from moisture and contamination at all times. Cement will be delivered in either pneumatic trailers and stored in a silo or on a flatbed trailer in one or two ton sacks.

b. Calcium Oxide (quicklime): Quicklime will be ASTM Designation C 977 (Specification for Quicklime and Hydrated Lime for Soil Stabilization) with a minimum available CaO content of 93%. Materials will be protected from moisture until used and be sufficiently dry to flow freely when handled. Quicklime will be furnished in dump trailers and immediately used or covered upon delivery or delivered in one or two ton sacks.

c. Fly Ash: Fly ash will be supplied by LA Ash from the Nisco, Formosa, or Madison Plant with a minimum available CAO content of 60%. Materials will be protected from moisture until used and be sufficiently dry to flow freely when handled. Fly ash will be furnished in dump trailers, pneumatic trailers, or sacks as necessary.

2.2 WATER

A. Water to be utilized for decontamination or equipment flushing/washing will come from the freshwater pond.

PART 3 EXECUTION

3.1 SLUDGE PIT SOLIDIFICATION

A. Prior to solidification, the sludge will be homogenized from the top to the bottom in each proposed mixing area. This will be accomplished utilizing the excavator bucket.

B. To verify treatment depth, the corners of the proposed solidification grids will be sounded to verify the exact sludge depth at each corner. Utilizing the area and depth, the volume of sludge will be verified. Using the unit weight of sludge measured at the start of solidification activities after the sludge is homogenized, the weight of the proposed solidification area will be calculated. The corresponding weight of each of the reagents will then be added, based on the optimum additive ratio determined in ENTACT's Pilot Study and modified as necessary to meet the performance criteria.

C. The mixing process will be conducted in-situ or ex-situ. The reagents will be added to the sludge at the specified ratios. The amount of reagent applied to each mixing grid will be recorded and documented. The reagents will be thoroughly mixed with the sludge until a homogenous mixture from side to side and top to bottom is created. No clumps of unmixed sludge larger than two inches will be allowed.

3.2 OIL PIT SOLIDIFICATION

A. Prior to sludge solidification, the sludge will be homogenized from the top to the bottom in each proposed mixing area. This will be accomplished utilizing the excavator bucket.

B. The corners of the proposed solidification grid will be sounded to determine overall depth at each corner. Utilizing the area and depth, the volume of sludge will be calculated. Using the unit weight of the oil pit sludge determined at the start of solidification activities after the sludge is homogenized, the weight of the proposed solidification area will be calculated. The corresponding weight of each of the reagents will then be added, based on the optimum additive ratio determined in ENTACT's Pilot Study modified as necessary to meet the performance criteria.

C. The mixing process will be conducted in-situ or ex-situ. The reagents will be added to the sludges at the specified ratios. The amount of reagent applied to each mixing grid will be recorded and documented. The reagents will be thoroughly mixed with the sludge until a homogenous mixture from side to side and top to bottom is created. No clumps of unmixed sludge larger than two inches will be allowed.

3.3 API UNIT/TANK SLUDGE SOLIDIFICATION

A. To verify treatment volume, the depth of the solidified sludge will be sounded in the tank or calculated in the containment area. Utilizing the area and depth, the volume of sludge will be verified. Using the unit weight of sludge measured at the start of solidification activities, the weight of the proposed solidification volume will be calculated. The corresponding weight of impacted soil and each of the reagents will then be added, based on the optimum additive ratio determined in ENTACT's Treatability Study and modified as necessary to meet the performance criteria.

B. The mixing process will be conducted in-situ (within the pits or tanks) or ex-situ (within the bermed tank containment areas). The impacted site soils and reagents will be added to the sludge at the specified ratios. The amounts of site soils and reagents applied to each mixing grid will be recorded and documented. The site soils and reagents will be thoroughly mixed with the sludge until a homogenous mixture is created. No clumps of unmixed sludge larger than two inches will be allowed.

3.4 EQUIPMENT

A. A conventional hydraulic excavator which distributes the equipment load across the full track width and length will be used to sound the mixing grids, and apply the reagents. A similar excavator will be employed for the solidification process.

B. A reagent delivery system such as a Pneumatic Dust Control Unit (or equivalent) may be used to off load the Portland cement and the quicklime. The reagent delivery system will be self contained, capable of withstanding 50 psi gauge pressure, with an emergency pressure relief valve or open-atmosphere venting capability. When practicable, reagents such as fly ash will be delivered via tarped dump trailer.

C. Site soils will be excavated from the soil excavation area(s) and transported to the proposed mixing areas via off-road dump trucks.

3.5 MIXING GRIDS

A. Mixing grids have been established in the sludge pit in order to effectively and efficiently deliver reagents at the proper ratio into the sludges to be solidified. The initial mixing grids have been determined based on available data. Once the sounding process begins, these pre-treatment mixing grid dimensions will change based on actual measured depths and unit weights of the sludges.

B. The as-built mixing grid dimensions will be surveyed for each completed mixing grid (e.g. "batch"). The locations of each mixing grid will be plotted daily on a red-line drawing maintained on site. The corners of each mixing grid will be plotted (Northing and Easting), along with the elevation (feet, MSL) for the top of treated SS material.

3.6 VERIFICATION SAMPLING AND TESTING

A. Each completed mixing grid corresponds to a "batch" of solidified material. Using full truckloads of reagent (~25 tons) for each batch, and the optimum additive ratios, each completed mixing grid will contain approximately 250 to 500 tons of sludge. The size of these mixing grids may be adjusted as necessary to facilitate mixing operations and as conditions require.

B. A set of six test cylinders (2" x 4" or 3" x 6") will be collected from each mixing grid. The solidified materials will be sampled by way of excavator bucket or by hand. The samples will be run through a 3/8" sieve and compacted into the cylinders in uniform lifts (3 minimum), each rodded to depth to ensure scarification between lifts in order to prevent potential slip failure plane surfaces.

D. Once collected and prepared, all samples will be labeled with the date, time, area, and grid # and will be placed in ziplock bags.

D. Each set of cylinders corresponding to a particular mixing grid will be tested for strength gain by pocket penetrometer at 1, 3, 5, 7, 14, 21 and 28 days. The penetrometer measures compressive strength in terms of tons/square foot (tsf), in equal .25 tsf increments.

E. In addition to the penetrometer testing conducted on the sample sets of solidified materials from each completed mixing grid, sample cylinders of solidified material will be transported to the laboratory for UCS testing at 28 days in accordance with ASTM D2166. Prior to UCS testing, filter paper will be placed on top and below each cylinder to analyze the presence of free liquids. The presence of free liquids will be documented in terms of "yes" they are present, or "no" they are not present on each cylinder that is broken.

E. The performance requirement for sludge placed into the RCRA C equivalent cell is to produce a solidified material with an unconfined compressive strength (UCS, per ASTM D1633) of at least 15 psi, while expressing no free liquids during UCS testing. If material does not meet these criteria, the entire batch will require retreatment utilizing additional reagents as necessary to passing results. Batches that are retreated will be sampled and tested in accordance with the requirements of this section.

END OF SECTION

SECTION 02300
GENERAL EARTHWORK

SECTION 02300

GENERAL EARTHWORK

PART 1 GENERAL

1.01 SECTION INCLUDES

A. The Contractor will furnish all labor, materials, tools, supervision, transportation, and installation equipment necessary to perform earthwork as specified herein and as shown on the Drawings.

B. The work of this Section will include, but not necessarily be limited to: excavating, separating, hauling, stockpiling, backfilling, compacting, and grading of structural fill, protective cover layer materials, and vegetative layer (topsoil) soils. The work of this Section may pertain in whole or in part to construction of the RCRA Subtitle C Cell subgrade and associated perimeter berm, interphase berm, liner protective cover, final cover system protective cover, vegetative layer (topsoil), and backfilling of liner and final cover system anchor trenches. The work of this Section also includes backfilling of other areas with non-structural backfill, and dewatering and protection of the work.

1.02 RELATED SECTIONS

A. Section 02071 - Geotextile

B. Section 02072 - Geosynthetic Clay Liner

C. Section 02073 - Geonet and Geocomposites

D. Section 02075 - Geomembranes

E. Section 02610 - High Density Polyethylene (HDPE) Pipes and Fittings

F. Section 02920 - Seeding

1.03 REFERENCES

A. Latest version of American Society for Testing and Materials (ASTM) standards:

1. ASTM D422. Standard Test Method for Particle-Size Analysis of Soils.
2. ASTM D698. Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3)).
3. ASTM D1556. Standard Test Method for Density of Soil in Place by the Sand-Cone Method.

4. ASTM D1557. Standard Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3)).
5. ASTM D2216. Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.
6. ASTM D2487. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System).
7. ASTM D2974. Standard Test Methods Moisture, Ash, and Organic Matter of Peat and Other Organic Soils.
8. ASTM D4318. Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.
9. ASTM D4972 Standard Test Method for pH of Soils.
10. ASTM D6938. Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth).

B. Construction Quality Assurance (CQA) Plan.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. Construction of the earthwork components of the project will be monitored as outlined in the CQA Plan.

B. The Contractor will be aware of the activities set forth in the CQA Plan and will account for these activities in the construction schedule.

1.05 EXISTING CONDITIONS

A. The Contractor will comply with applicable regulations in locating and providing clearance for all underground and above ground utilities prior to beginning construction activities.

1.06 SUBMITTALS

A. Structural Fill:
   1. It is anticipated that the Contractor will be using an on-site soil source for the structural fill. The Contractor will select soil that meets the requirements specified in this Section.
   2. The Contractor will perform a pre-construction testing program on each proposed source of structural fill material in accordance with the tests specified for structural fill in Table 02300-1.

B. Protective Cover:
   1. It is anticipated that the Contractor will be using impacted soils for the liner system protective cover and an on-site soil source of clean soil (non-impacted) for

the final cover system protective cover. Other source(s) will be utilized as necessary to complete the work.

2. The Contractor will perform a pre-construction testing program on each source of protective cover soils. Each source will be evaluated for potential use as protective cover by performing the pre-construction laboratory tests specified for protective cover in Table 02300-1.

C. Vegetative Layer (Topsoil):
   1. It is anticipated that the Contractor will be using an on-site soil source for the vegetative layer (topsoil).
   2. The Contractor will perform a pre-construction testing program on each source of vegetative layer soil (topsoil). Each source will be evaluated for potential use as vegetative layer (topsoil) by performing the pre-construction laboratory tests specified for the vegetative layer soil (topsoil) in Table 02300-1.

PART 2 PRODUCTS

2.01 STRUCTURAL FILL

A. Material requirements for structural fill soil are presented in Table 02300-2 of this Section.

B. Water for moisture conditioning the structural fill will be obtained from the freshwater pond or other source as required.

C. When subgrade proof-rolling is required, the Contractor will use loaded soil hauling equipment with 20 cubic yard (min.) capacity, or equipment with equivalent ground pressure.

D. The Contractor will furnish, operate, and maintain equipment suitable for excavating, hauling, placing, spreading, and compacting the structural fill material in lifts of relatively uniform thickness.

E. The Contractor will furnish, operate, and maintain grading equipment as is necessary to produce uniform layers, sections, and smoothness of grade for compaction and drainage.

F. The Contractor will use a water truck capable of applying water uniformly and in controlled quantities to moisture condition the structural fill.

2.02 PROTECTIVE COVER

A. Material requirements for protective cover soil are presented in Table 02300-2 of this Section.

B. For the liner system protective cover, impacted soils meeting the requirements presented in Table 02300-2 may be used.

C. For the final cover system protective cover, clean (non-impacted) soil meeting the requirements presented in Table 02300-2 will be used.

D. The Contractor will furnish, operate, and maintain equipment necessary for excavating, hauling, placing, and spreading the protective cover soil.

2.03 VEGETATIVE LAYER (TOPSOIL)

A. Material requirements for vegetative layer soil (topsoil) are presented in Table 02300-2 of this Section.

B. Topsoil material should be from an on-site or off-site source of surficial loamy soil containing sufficient amounts of nutrients and organic matter to produce and sustain the specified grassy vegetation. Natural soils as well as appropriate compost-amended soils meeting the specified properties may be used as vegetative layer soil (topsoil).

C. The Contractor will furnish, operate, and maintain equipment necessary for excavating, hauling, placing, and spreading the vegetative layer soil (topsoil).

2.04 BACKFILL (NON-STRUCTURAL)

A. Non-structural backfill should meet the product requirements listed in Part 2, Section 2.01 for structural fill.

PART 3 EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any of the work described in this Section, the Contractor will inspect the installed work of all other Sections and verify that all work is complete to the point where the work of this Section may properly commence without adverse impact.

3.02 EROSION PROTECTION AND SEDIMENT CONTROL

A. Prior to implementing any of the work described in this Section, the Contractor will install erosion and sediment controls features.

B. The Contractor will plan and execute construction and earthwork using methods to control surface drainage from disturbed areas, cuts and fills, borrow areas, and stockpiles, in order to prevent erosion and sedimentation, and will provide temporary control measures such as silt fence, riprap, rock berms, sediments traps, erosion mats, and temporary surface water diversion berms as required to satisfy applicable project and regulatory requirements.

C. The Contractor will maintain all erosion protection and sediment control features throughout construction.

3.03 FIELD QUALITY ASSURANCE

A. The QA/QC Manager will perform field quality assurance testing of all structural fill. Details and minimum frequencies of quality assurance testing for the structural fill are given in the CQA Plan. The Contractor will take the minimum testing frequencies into account in planning his construction schedule.

B. No quality assurance testing is required for the protective cover and vegetative cover (topsoil) soils; however, installation of the liner and final cover protective cover layers, and the vegetative layer (topsoil), will be monitored by the QA/QC Manager as required by the CQA Plan.

C. The Contractor will not place a lift of structural fill until the underlying subgrade or lift of structural fill has been tested by the QA/QC Manager

D. Small perforations in the structural fill caused by nuclear density test probe locations or other perforations of similar size will be backfilled and tamped in place. Perforations in the structural fill caused by larger perforations (e.g., sand cone test locations or other perforations of similar size) will be backfilled and compacted.

E. If a defective area is discovered, the QA/QC Manager will determine the extent and nature of the defect. After the extent and nature of a defect have been determined, the Contractor will correct the deficiency so that is repaired and meets the specifications.

3.04 SITE PREPARATION – RCRA CELL

A. Before the start of grading at the RCRA Cell and related site borrow and stockpile areas, the Contractor will establish the location and extent of utilities in the affected work areas. The Contractor will remove and relocate lines (with utility provider's notification and approval as required) which obstruct construction and are not to be relocated as a part of the work covered by these specifications.

B. The Contractor will maintain, protect, reroute, or extend as required existing utilities which are to remain in-place/in-service.

C. The Contractor will develop access to the construction area.

D. Diversion ditches will be constructed by the Contractor as required to divert run-on around the construction area.

3.05 EXCAVATION - GENERAL

A. Excavation will be performed in the designated excavation/borrow areas. When unstable material is encountered at the bottom or sides of an excavation, the Contractor will remove it to a minimum depth of 1-ft and backfill to the proper grade with

appropriate material. The lateral extent of additional excavation will be determined by the QA/QC Manager.

B. Surplus excavated soil will be transported to stockpile or placement locations, as indicated on the Drawings.

C. Excavated soils that are unsuitable for their intended use will be segregated from suitable soils and transported to a designated stockpile location.

3.06 EXCAVATION - TRENCHES

A. Excavation of trenches will be performed in such a manner as to form a suitable trench in which to place pipe or anchor geosynthetics (as appropriate) and so as to cause the least disturbance or inconvenience to the surroundings.

B. Trench width and depth will be as noted on the Drawings.

C. The Contractor will align trench as shown on the Drawings unless a change is necessary to miss a previously unforeseen obstruction.

D. When unstable soil is encountered at the trench bottom, the Contractor will remove it to a depth required to assure support of the pipeline and backfill to the proper grade with the pipe bedding material.

3.07 OBSTRUCTIONS

A. The Contractor is responsible for locating obstructions and potential obstructions.

B. The Contractor will exercise due care in excavating adjacent to existing obstructions and will not disturb same.

3.08 STRUCTURAL FILL PLACEMENT AND COMPACTION

A. Earthwork performed to achieve the liner system subgrade, berms (perimeter berms, interphase berms, etc.), and other areas requiring structural fill, will be constructed to the lines and grades shown on the Drawings.

B. Structural fill will be placed in 9 inch (maximum) loose lifts that results in an average compacted lift thickness of not more than 6 inches. The QA/QC Manager may allow thicker lifts up to 12-inch (loose)/9-inch (compacted) if the Contractor is able to demonstrate that the full lift thickness achieves the required compaction criteria. Compaction will be carried out using a static padded-foot or sheepsfoot compactor having a minimum weight of 18,000 lbs.

C. Each lift of structural fill will be compacted to achieve ≥95% of the maximum dry density and within 4 percentage points dry to 4 percentage points wet of optimum as determined from the Standard Proctor compaction test (ASTM D698).

D. If the moisture content of the structural fill is too dry or too wet to achieve acceptable compaction, the Contractor will wet or dry the soil as needed to achieve the correct moisture content. Wetting will be accomplished using a water truck and spray nozzle, unless the QA/QC Manager approves an alternative method. During wetting or drying, the soil will be processed routinely using disking devices or other mixing equipment so that uniform moisture conditions are obtained.

E. When placing and compacting structural fill across wet or unstable subgrade areas or when placing fill material below the water table, a thicker first lift may be used as a bridge lift**,** in order to provide a sufficiently dry/firm and stable base on which to place and compact subsequent lifts.

F. No structural fill material will be placed, spread, or compacted unfavorable weather conditions (e.g., below freezing weather, in standing water), or during periods of heavy precipitation.

3.09 NON-STRUCTURAL BACKFILL PLACEMENT OUTSIDE CELL FOOTPRINT

A. Non-structural backfill material will be placed in the Sludge Pit, Oil Pit, API Separators, and other excavation areas outside the RCRA cell footprint as necessary to reach the uppermost water bearing unit at a minimum. Additional fill may be placed to reach the existing surrounding grade if requested by the MCP.

B. Non-structural backfill will be placed in 12-inch (nominal) loose lifts. In general, each lift will be spread with a bulldozer. Compaction of each lift will be carried out using heavy equipment such as a static/vibratory padded-foot or smooth-drum roller, the tracking of heavy construction equipment, or tamping with the bucket of a hydraulic excavator.

C. The QA Manager may allow thicker lifts if the Contractor is able to demonstrate that the thicker lift produces a firm and stable base that is suitable for placement and compaction of subsequent lifts without exhibiting excessive rutting, pumping, softness, or deflections. Similarly, when placing and compacting non-structural fill across wet or unstable subgrade areas or when placing fill material below the water table, a thicker first lift may be used as a bridge lift.

3.10 PROTECTIVE COVER PLACEMENT AND COMPACTION

A. Protective cover soil does not require compaction control; however, it should be stable for construction traffic.

B. Care will be exercised in placement so as not to shift, wrinkle or damage the underlying geosynthetic layers. Drivers will proceed with caution when trafficking on the protective cover materials on or adjacent to the leachate collection system. Drivers will prevent spinning of tires and will not make quick stops or sharp turns.

C. Protective cover should generally be placed in an up-slope direction for slopes steeper than three to four percent.

D. Protective cover will be placed such that the minimum soil thickness given below is maintained between construction equipment and underlying geosynthetics.

Allowable Equipment Ground Pressure (psi)	Minimum Thickness of Soil Overlying Geosynthetics (in.)
<5	12
<10	18
<20	24
>20	36

3.11 VEGETATIVE LAYER (TOPSOIL) PLACEMENT AND COMPACTION

A. Vegetative layer soil should be spread and tracked-in with a bulldozer, or otherwise placed in a similar manner that does not heavily compact the soil so that it provides a stable layer that is a suitable seedbed for the specified seeding and establishment of grassy vegetation. Excessively wet or dry material should not be placed.

B. Vegetative layer soil will generally be placed in an up-slope direction.

C. Seeding activities (including fertilizing and mulching) will take place as soon as practicable after topsoil placement.

D. Vegetative layer soil will be placed such that the minimum soil thickness given below is maintained between construction equipment and underlying geosynthetics.

Allowable Equipment Ground Pressure (psi)	Minimum Thickness of Soil Overlying Geosynthetics (in.)
<5	12
<10	18
<20	24
>20	36

3.12 PUMPING AND DRAINAGE

A. At all times during construction, the Contractor will provide and maintain proper equipment and facilities to remove water entering the construction area so as to obtain satisfactory working conditions.

B. The Contractor will be responsible for controlling ground-water, surface-water run-off and run-on around the construction area.

C. Surface water will be pumped or drained from the construction area in order to maintain the construction area free from standing water. Surface water will be pumped or drained in a manner which prevents flow or seepage back into the construction area.

3.13 SURVEYING AND CONSTRUCTION TOLERANCES

A. The Contractor will construct the liner system subgrade to within a tolerance of -0.2 ft to +0.2 ft of the grades indicated on the Drawings. Other structural fill, protective cover layers, and the vegetative (topsoil) layer will be constructed to within a tolerance of ± 0.2 ft of the grades indicated on the Drawings, and the minimum layer thicknesses will be met.

3.14 PROTECTION OF WORK

A. The Contractor will use all means necessary to protect all prior work, including all materials and completed work of other Sections.

TABLE 02300-1

PRE-CONSTRUCTION TESTING REQUIREMENTS FOR STRUCTURAL FILL, PROTECTIVE COVER, AND VEGETATIVE LAYER (TOPSOIL)

TEST	**METHOD**
Structural Fill	
Particle Size (Sieve) Analysis	ASTM D422
Atterberg Limits	ASTM D4318
USCS Engineering Classification	ASTM D 2487
Natural (as-received) Moisture Content	ASTM D2216
Standard Proctor Compaction	ASTM D698
Protective Cover	
Particle Size (Sieve) Analysis	ASTM D422
Vegetative Layer (Topsoil)	
Organic Matter	ASTM D2974
Particle Size (Sieve) Analysis with Hydrometer	ASTM D422
Soil pH	ASTM D4972
Soil Agronomy: · Routine Analysis (Macronutrients) NO_3, P, K, Ca, Mg, Na, Conductivity	Topsoil Analysis and Fertilizer Recommendations from a Texas Certified Agronomist

Note: Indicate to the agronomy laboratory the type of vegetation to be grown, whether to be irrigated, and whether soil source was previously fertilized. Indicate to the agronomy laboratory that fertilizer recommendations are to be based on new establishment of forage using the minimum fertilizer requirement for establishment.

TABLE 02300-2
MATERIAL SPECIFICATIONS FOR
STRUCTURAL FILL, PROTECTIVE COVER, AND VEGETATIVE LAYER (TOPSOIL)

PROPERTY	QUALIFIER	SPECIFIED VALUES	TEST METHOD
Structural Fill			
Material Quality	--	Relatively homogeneous clean soil that is free of organic matter, debris, frozen material, deleterious materials, and excess moisture	Field Observation
Unified Soil Classification	Classification	CL, CH, SC, SM, SP, or SW	ASTM D2487
Particle Size	Maximum	3 in.	ASTM D422
Lift Thickness	Maximum	9 in. loose(1) 6-in. compacted(1)	Field Observation
Field Moisture Content and Density	--	Meet compaction criteria(2)	ASTM D2216, ASTM D6938
Protective Cover			
Material Quality	--	Relatively homogeneous soil that is free of debris, foreign objects, and sharp objects	Field Observation
Particle Size	Maximum	2 in.	ASTM D422
Vegetative Layer (Topsoil)			
Material Quality	--	Easily cultivated, relatively homogeneous clean soil that is free of objectionable material including gravel, large roots, stumps, wood, brush, debris, hard clods, clay balls, hardpan, debris, or other deleterious materials.	Field Observation
Particle Size	Maximum	2 in.	ASTM D422
pH	Range	6-9	ASTM D4972

Notes:

(1) The QA/QC Manager may allow thicker lifts up to 12-inch (loose)/9-inch (compacted) if the Contractor is able to demonstrate that the full lift thickness achieves the required compaction criteria.

(2) Onsite QA/QC Manager will perform pre-construction testing program to develop compaction criteria – see Section 3.10(C).

[END OF SECTION]

SECTION 02302
WASTE PLACEMENT AND COMPACTION

SECTION 02302

WASTE PLACEMENT AND COMPACTION

PART 1 GENERAL

1.01 SECTION INCLUDES

A. The Contractor will furnish all labor, materials, tools, supervision, transportation, and installation equipment necessary to place and compact waste in the RCRA Subtitle C Cell shown on the Drawings. This section also includes material, placement, and compaction requirements for the internal berms located within the cell.

1.02 RELATED SECTIONS

A. Section 02071 - Geotextile

B. Section 02072 - Geosynthetic Clay Liner

C. Section 02073 - Geonet and Geocomposites

D. Section 02075 – Geomembranes

E. Section 02300 – Earthwork

F. Section 02610 - High Density Polyethylene (HDPE) Pipes and Fittings

1.03 REFERENCES

A. Latest version of American Society for Testing and Materials (ASTM) standards:

1. ASTM D422. Standard Test Method for Particle-Size Analysis of Soils.
2. ASTM D698. Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3)).
3. ASTM D1556. Standard Test Method for Density of Soil in Place by the Sand-Cone Method.
5. ASTM D2216. Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.
6. ASTM D2487. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System).
8. ASTM D4318. Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.
9. ASTM D6938. Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth).

1.04 CONSTRUCTION QUALITY ASSURANCE

A. Waste placement and compaction is not part of the formal CQA program, but will be periodically monitored by the QA/QC Manager.

PART 2 PRODUCTS

2.01 SOIL USED TO CONSTRUCT INTERNAL CELL BERMS

A. Impacted soil meeting the material particle size and USCS soil classification requirements for structural fill (Table 02300-2 of Section 02300) may be used to construct the internal cell berms.

B. Alternately, non-impacted soil (structural fill) meeting Section 02300 may be used to construct the internal cell berms.

PART 3 EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any of the work described in this Section, the Contractor will inspect the installed work of all other Sections and verify that all work is complete to the point where the work of this Section may properly commence without adverse impact.

3.02 CONTACT WATER MANAGEMENT AND CONTROL

A. Storm water runoff, precipitation, or other water having come in contact with the waste is defined as contact water. [Water that has infiltrated into and through the waste mass and is collected in the drainage layers of the liner system and in the sumps is defined as leachate.] Contact water will be collected and controlled during waste placement and compaction operations, as will leachate.

B. Contact water generation will be minimized to the extent practicable through the use of methods such as tarps or daily cover, run-on and run-off control berms, and by phased filling/staged waste placement to minimize the amount of exposed (open) waste to the extent practicable at any given point in time.

C. Contact water will be managed and disposed in the same manner as leachate. Collected contact water must be routed to and temporarily stored on lined areas provided that the head on the primary liner is maintained at <1-ft, and must not allowed to flow off of lined areas or otherwise discharge from the site.

D. When waste placement is “above grade” (i.e., waste slopes are at higher elevations than the perimeter berm to which they slope towards), the Contractor will take particular care to prevent the runoff of potentially contaminated water (i.e., contact water) through the use of temporary diversion berms, temporary diversion ditches, tarps, or the like to

route clean water off of and away from the waste, and to route contact water into designated holding areas/collection areas of the lined cell.

3.03 INTERNAL CELL BERMS PLACEMENT AND COMPACTION

A. The internal cell berms will be constructed to the dimensions and at the locations shown on the Drawings.

B. The internal cell berms will be placed in 9 inch (maximum) loose lifts that results in an average compacted lift thickness of not more than 6 inches. The QA/QC Manager may allow thicker lifts up to 12-inch (loose)/9-inch (compacted) if the Contractor is able to demonstrate that the full lift thickness achieves the required compaction criteria. Compaction will be carried out using a static padded-foot or sheepsfoot compactor having a minimum weight of 18,000 lbs.

C. Each lift of the internal cell berms will be compacted to achieve ≥95% of the maximum dry density and within 4 percentage points dry to 4 percentage points wet of optimum as determined from the Standard Proctor compaction test (ASTM D698).

D. If the moisture content of the soil for the internal cell berms is too dry or too wet to achieve acceptable compaction, the Contractor will wet or dry the soil as needed to achieve the correct moisture content. Wetting will generally be accomplished using a water truck and spray nozzle. During wetting or drying, the soil will be processed routinely using disking devices or other mixing equipment so that uniform moisture conditions are obtained.

E. No berm material will be placed, spread, or compacted unfavorable weather conditions (e.g., below freezing weather, in standing water), or during periods of precipitation.

F. The internal cell berm placement and compaction equipment must comply with the ground pressure and separation distance requirements set forth below in Section 3.04 to prevent shifting or damage of the underlying liner system geosynthetics.

3.04 WASTE PLACEMENT AND COMPACTION – FULL-SCALE OPERATIONS

A. Waste composed of solidified sludge pit material (i.e., sludges that have been solidified with reagents) will be subject to the waste placement and compaction test fill program (see Section 3.05) prior to full-scale waste placement in the cell.

B. Upon successful completion of the solidified material waste placement and compaction test fill program, waste placement and compaction of the solidified sludge pit material may proceed, in accordance with the guidelines (e.g., equipment, number of passes, other placement or moisture conditioning restrictions) derived from the outcome of that program. The other waste materials to be disposed of in the cell are expected to be similar or stronger material and are of a much smaller total quantity of the cell volume, and therefore do not need a test fill.

C. Waste will be placed in 1-ft (nominal) thick maximum lifts. Exceptions may be made for demolition material/debris that is not practical to be size-reduced to this extent. Demolition material/debris having particle sizes greater than 1-ft in any dimension will not be placed within 2-ft of the top of the protective cover layer component of the liner system.

D. Demolition material/debris will be integrated into the overall waste mass so that it is backfilled and surrounded by competent waste material and that voids are filled.

E. Waste will be compacted to at least 90% of its standard Proctor maximum dry density. Quality control or quality assurance testing is not required on an ongoing basis, provided that the placement techniques are consistent with the successful test fill program, and visual observation reveals consistent appearance, consistency, structural competence, and workability as in the test fill program.

F. Waste will be placed at a maximum interim slope steepness of 7%, and final slope steepness of 5.8%. Internal cell berms will be used as needed to buttress placed waste as needed based on the maximum interim and final slope steepness – to provide practicable staging and work areas for waste placement up to the final waste grades of the cell.

G. Care will be exercised during placement of waste within 3-ft of the top of the liner system, placement so as not to shift, wrinkle or damage the underlying geosynthetic layers. Drivers will proceed with caution when trafficking on the protective cover materials on or adjacent to the leachate collection system. Drivers will prevent spinning of tires and will not make quick stops or sharp turns.

H. Waste will be placed such that the minimum waste material thickness given below is maintained between construction equipment and underlying geosynthetics.

Allowable Equipment Ground Pressure (psi)	**Minimum Thickness of Material Overlying Geosynthetics (in.)**
<5	12
<10	18
<20	24
>20	36

3.05 WASTE PLACEMENT AND COMPACTION – TEST FILL, SOLIDIFIED SLUDGE PIT MATERIAL

A. Prior to full-scale waste placement and compaction in the cell, the solidified sludge pit waste will be subject to a test fill program. The other waste materials are expected to be similar or stronger material and are of a much smaller total quantity of the cell volume, and therefore do not need a test fill.

B. The test fill will be constructed using representative solidified sludge pit waste that has achieved its designated unconfined compressive strength (UCS) and then has been excavated (thereby breaking up the solidified material) and transported to a test fill area of the lined cell.

C. During test fill construction, placement and compaction equipment must comply with the ground pressure and separation distance requirements set forth below in Section 3.04 to prevent shifting or damage of the underlying liner system geosynthetics.

D. The test fill will be placed and compacted by the Contractor using the same equipment and procedures proposed for use by the Contractor during full-scale operations. The test fill will be approximately 30-ft wide and 50-ft long, and will be composed of at least two lifts.

E. Conduct the test fill program as follows:

1. The first lift is a trial lift for visual evaluation only. Spread and place the first lift.

2. Compact the material in the first lift with the proposed compaction equipment, lift thickness (1-ft maximum), and desired number of passes.

3. Visually evaluate the structural competency and general workability of the first lift, for general constructability and strength. If visually suitable, proceed with the next steps. If unstable or marginal, consider performing additional passes, using thinner lifts, or altering the moisture content (wetting or drying as needed to be closer to the standard Proctor optimum moisture content).

4. Upon completion of a visually suitable first lift, place and spread the second lift above the first lift. Compact the second lift. Obtain samples for oven moisture content testing to record the "as-placed" moisture content, for use in evaluating results and comparing to the optimum moisture content from the standard Proctor compaction curve for this waste material.

5. Perform two in-place density tests on the compacted lift using oven laboratory methods (sand cone). If desired, an attempt may be made at the same time to perform field methods (nuclear moisture/density tests) in order to derive data from which to correlate to the laboratory moisture/density methods. However, the content of the waste material may make nuclear test methods infeasible.

6. The density criterion for a lift is $\geq$ 90% of its standard Proctor maximum dry density. If the second lift passes the density criterion, the outcome of the test fill program (equipment types, placement and compaction technique, moisture conditioning methods if any, lift thickness, and number of passes will be used as the requirements for full-scale waste placement operations for the solidified sludge waste materials.

7. If the density criterion is not met, the lift will be re-worked through additional compaction passes, or other additional compaction techniques, and Steps 4 through 6 will be repeated until passing results are obtained.

F. Upon successful completion of the solidified material waste placement and compaction test fill program, waste placement and compaction may proceed, in accordance with the guidelines (e.g., equipment, number of passes, other placement or moisture conditioning restrictions) derived from the outcome of that program.

3.06 PROTECTION OF WORK

A. The Contractor will use all means necessary to protect all prior work, including all materials and completed work of other Sections.

[END OF SECTION]

SECTION 02500
SURVEYING

SECTION 02500
SURVEYING

PART 1 GENERAL

1.1 WORK INCLUDED

A. ENTACT will provide all materials, items, operations or methods specified, listed or scheduled on the Construction Drawings and Specifications including all materials, labor, equipment and incidentals necessary and required to conduct proper surveys required to stake, layout, and control the work.

B. Included in this section are the requirements for providing a tie-in survey to Texas State Plane Coordinates, verification of existing topographic conditions, surveying the subgrade boundaries and elevations of the cell subgrade, top of foundation layer, top of waste, top of cover soil, and top of vegetative layer. Additional as-built surveys will include storm water swale locations, gas vent locations, and final topographic surveys of backfilled excavation and other disturbed areas. ENTACT will establish and protect sufficient site monuments and control points to control field surveying activities.

1.2 REGISTERED SURVEYOR

A. Any field surveying of property boundaries or land monuments must be performed under the direct supervision of a Registered Professional Land Surveyor (R.P.L.S.) licensed in the State of Texas.

B. ENTACT will provide complete as-built record drawings for the Malone Services Company Superfund Site, signed by a R.P.L.S.

1.3 RELATED SECTIONS

A. Section 01300 – Submittals
B. Section 02020 – Erosion and Sediment Controls
C. Section 02055 – Decontamination/Dismantling of Tanks and Process Equipment
D. Section 02085 – Monitoring Well Abandonment
E. Section 02200 – Solidification Field Pilot Study
F. Section 02205 – Solidification Field Pilot Study (Alternative PC Slurry Method)

1.4 PROJECT RECORD DOCUMENTS

A. ENTACT will maintain on-site a complete, accurate log documenting any and all changes and control of survey work as it progresses.

B. Upon completion of the work, ENTACT will submit the Remedial Action Final Report to the USEPA as detailed in Section 01300 – SUBMITTALS.

1.5 QUALITY CONTROL

A. ENTACT will provide certified survey results to the USEPA and TCEQ on a timely basis as the work progresses. The survey results will be in the form of an as-built drawing and/or a table of survey results.

PART 2 PRODUCTS

2.1 GENERAL

A. The following relative positional accuracies for the topographic survey will be:

Vertical Accuracy	± 0.1 ft
Horizontal Accuracy	± 0.2 ft

B. Slope tolerances of final grade will be ± 10% of design grade, with a maximum allowable slope of 3:1 (horizontal to vertical) on the outer edge of the cell slopes.

2.2 SURVEYS

A. Surveys will be generated as follows:

1. Original topographic survey showing existing grade elevations in all areas where land disturbances are anticipated
2. Excavation area survey showing line and grade of all areas where material has been excavated (soil excavation areas, sludge removal areas, etc)
3. Cell subgrade survey showing elevation prior to placing the cell geosynthetic liner system
4. Cell bottom liner survey showing panel layout of geomembrane including all testing locations and repair locations
5. Cell foundation layer survey
6. kCell top of waste layer survey

7. Cell cap liner survey showing panel layout of geomembrane including all testing locations and repair locations
8. Cell top of cover soil survey
9. Cell top of vegetative layer survey including all other cell features including stormwater conveyance swales, riprap, access roads, piping, etc.
10. Surveys that identify the location and elevations of utilities and wells installed and/or left on-site.

2.3 Submittals

A. Submit areal, volumetric, and line & grade surveys as may be conducted from time to time. A copy of all survey data will be included in the Remedial Action Final Report.

B. Submit as-built record drawings for surveys listed in Section 2.2.

PART 3 EXECUTION

3.1 ESTABLISHMENT OF SITE SURVEY CONTROL POINTS

A. Prior to starting work, ENTACT will install survey control points which are tied-in to Texas State Plane Coordinates to be used as reference points for all work on site.

B. ENTACT will exercise extreme care during the execution of all phases of the work to minimize any disturbance to these control points.

C. These control points will be protected during the life of the remedial action and will be replaced as needed, should they become damaged, destroyed, or relocated as necessary.

3.2 TIE-IN SURVEY TO TEXAS STATE PLANE COORDINATES

A. A survey will be conducted and a record drawing will be developed to document the existing site topography and existing site conditions. This record drawing will be used as the base map from which the entire project drawing files will be based. This drawing will identify the site control points according to the Texas State Plane Coordinate System.

B. This survey and resulting site control points will be tied-in to the nearest U.S. National Geodetic Survey monuments. Horizontal control will be defined with respect to North American Datum 1983 (NAD83). Vertical control will be defined with respect to National Geodetic Vertical Datum 1988 (NGVD88).

3.3 SURVEY REQUIREMENTS

A. ENTACT will record and document all required survey data with respect to the site control points provided. All record elevations will be established in units of feet with respect to Mean Sea Level (MSL). All planar locations will be recorded as Northings (N) and Eastings (E) in the Texas State Plane Coordinate System.

B. ENTACT will establish lines and grades, locate and layout by instrumentation or other appropriate means, site features to be constructed including necessary stakes for horizontal limits of excavation areas, sludge mix areas, cell location, and stakes for all earthwork slopes and elevations.

C. ENTACT will ensure that the elements of the engineered cap system are documented including foundation layer thickness, cover soil thickness, vegetative layer thickness, finish grade elevations, and slopes and locations for the storm water swales.

D. ENTACT will establish construction lines and grades.

E. ENTACT will furnish all materials and accessories (i.e., grade markers, stakes, pins, spikes, etc.) required for the proper location of grade points and lines.

3.4 EXISTING MONITORING WELLS

A. All existing monitoring wells, injection wells, and the water well will be located and documented via survey prior to the start of work.

3.5 FINAL SITE GRADING AND OTHER SUBMITTALS

A. Following placement of the vegetative soil cover, ENTACT will provide a final topographic survey of the final site grade.

B. In addition, other as-built drawings to be submitted include surveys listed in Section 2.2.

3.6 SURVEYS FOR MEASUREMENT AND RECORD KEEPING PURPOSES

A. ENTACT will perform areal and volumetric surveys, including surveys to establish measurement reference lines, surface areas and volumes as necessary.

B. ENTACT will calculate and certify quantities and provide survey results and calculations in certified R.P.L.S. documents within the Remedial Action Final Report.

END OF SECTION

SECTION 02610
HDPE PIPES AND FITTINGS

SECTION 02610

HIGH DENSITY POLYETHYLENE (HDPE) PIPES AND FITTINGS

PART 1 GENERAL

1.01 SECTION INCLUDES

A. The Contractor will furnish all labor, materials, tools, supervision, transportation, and installation equipment necessary for installation of all high density polyethylene (HDPE) pipes, fittings and appurtenances required to complete the work, in accordance with the Drawings and these Specifications.

B. The Contractor will be prepared to install HDPE pipes and fittings in conjunction with the aggregates and geotextiles, and other related components of the work.

1.02 RELATED SECTIONS

A. Section 02060 - Aggregates

B. Section 02071 - Geotextile

C. Section 02072 - Geosynthetic Clay Liner

D. Section 02073 – Geonet and Geocomposites

E. Section 02075 – Geomembranes

F. Section 02300 - General Earthwork

1.03 REFERENCES

A. Latest version of the American Society for Testing and Materials (ASTM) standards:

1. ASTM D1248. Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable.
2. ASTM D1603. Standard Test Method for Carbon Black Content in Olefin Plastics.
3. ASTM D1693. Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics.
4. ASTM D2657. Standard Practice for Heat Fusion Joining for Polyolefin Pipe and Fittings.
5. ASTM D2837. Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products.
6. ASTM D3350. Standard Specification for Polyethylene Plastics Pipe and Fittings Materials.

7. ASTM F714. Standard Specification for Polyethylene (PE) Plastics Pipe (DR-PR) Based on Outside Diameter.
8. ASTM F1473. Standard Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins.

1.04 CONSTRUCTION QUALITY ASSURANCE

A. Installation of the HDPE pipe components of the project, while not part of the formal CQA program, will be periodically monitored by the QA/QC Manager.

1.05 EXISTING CONDITIONS

A. The Contractor will comply with applicable regulations in locating and providing clearance for all underground and above ground utilities prior to beginning construction activities.

1.06 WARRANTY

A. The Contractor will furnish written warranties obtained from the manufacturer and the Contractor against defects in materials and workmanship in accordance with ASTM D3350 and ASTM F714.

PART 2 PRODUCTS

2.01 HDPE COMPOUND

A. The HDPE pipes and fittings will be manufactured from new, high performance, high molecular weight, high density polyethylene resin conforming to ASTM D1248 (Type III, Class C Category 5, Grade P 34), ASTM D3350 (e.g., Cell Classification PE 345434 C or PE 445474 C), and having a Plastic Pipe Institute (PPI) Rating of PE 3408 or PE 4710. Material specifications for the HDPE pipes and fittings are presented in Table 02610-1.

B. The resin will be pre-compounded. In plant blending of non-compounded resins will not be permitted. The polyethylene compound will contain between 2 to 3 percent carbon black.

C. The polyethylene compound will have a minimum resistance of 125 hours when tested for environmental stress crack in accordance with requirements of ASTM D1693, Procedure B.

2.02 HDPE PIPES AND FITTINGS

A. All HDPE pipes and fittings will comply with the ASTM F714 and with the requirements shown in Table 02610-1 of this Section.

B. All HDPE pipes and fittings will have the standard dimension ratio (SDR) as indicated on the Drawings. HDPE pipes and fittings and the embedment will be designed to ensure that external loads will not subsequently cause a decrease in the vertical cross-section dimension (deflection) greater than the percentages listed below:

SDR	ALLOWABLE RING DEFLECTION (percent)
26	6.5
21	5.2
19	4.7
17	4.2
15.5	3.9
13.5	3.4
11.0	2.7

C. HDPE pipes will be supplied in standard laying lengths not exceeding 50 feet.

D. HDPE pipes will be furnished non-perforated (solid) or perforated as specified on the Drawings.

E. HDPE pipes and fittings will be homogeneous throughout and free of visible cracks, holes (other than intentional manufactured perforations), foreign inclusions, or other deleterious effects, and will be uniform in color, density, melt index and other physical properties.

F. Fittings at the ends of pipes will consist of HDPE end caps unless indicated otherwise on the Drawings.

2.03 IDENTIFICATION

A. The following will be continuously indent printed on the pipe, or spaced at intervals not exceeding 5 feet:
   1. Name and/or trademark of the pipe manufacturer.
   2. Nominal pipe size.
   3. Standard dimension ratio (SDR).
   4. The letters PE followed by the polyethylene grade per ASTM D1248, followed by the Hydrostatic Design basis in 100's of psi (e.g., PE 3408 and PE 4710).
   5. Manufacturing Standard Reference (e.g., ASTM F714-1).

6. A production code from which the date and place of manufacture can be determined.

PART 3 EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any of the work described in this Section, the Contractor will inspect the installed work of all other Sections and verify that all work is complete to the point where the work of this Section may properly commence without adverse impact.

3.02 HANDLING AND PLACEMENT

A. The Contractor will comply with the HDPE pipe Manufacturer's recommendations for handling, storing, and installing HDPE pipes and fittings.

B. The Contractor will exercise care when transporting, handling and placing HDPE pipes and fittings, such that they will not be cut, kinked, twisted, or otherwise damaged.

C. Ropes, fabric or rubber-protected slings and straps will be used when handling HDPE pipes. Slings, straps, etc. will not be positioned at butt-fused joints. Chains, cables or hooks will not be inserted into the pipe ends as a means of handling pipe.

D. Pipes or fittings will not be dropped onto rocky or unprepared ground. Under no circumstances will pipes or fittings be dropped into trenches, or dragged over sharp and cutting objects.

E. HDPE pipes will be stored on clean level ground, preferably turf or sand, free of sharp objects which could damage the pipe. Stacking will be limited to a height that will not cause excessive deformation of the bottom layers of pipes under anticipated temperature conditions.

F. The maximum allowable depth of cuts, gouges or scratches on the exterior surface of HDPE pipes or fittings is 10 percent of the wall thickness. The interior of the pipes and fittings will be free of cuts, gouges and scratches. Sections of pipe with excessive cuts, gouges or scratches will be removed and the ends of the pipe rejoined.

G. Whenever pipe laying is not actively in progress, the open end of pipe that has been placed will be closed using a watertight plug.

3.03 INSTALLATION

A. General:
   1. All HDPE pipes and fittings will be installed in accordance with the manufacturer's instructions.

2. The Contractor will carefully examine all pipes and fittings for cracks, damage or defects before installation. Defective materials will be immediately removed from the site and replaced.
3. The interior of all pipes and fittings will be inspected, and any foreign material will be completely removed from the pipe interior before it is moved into final position.
4. Field-cutting of pipes, where required, will be made with a machine specifically designed for cutting pipe. Cuts will be carefully made, without damage to pipe or lining, so as to leave a smooth end at right angles to the axis of pipe. Cutter ends will be tapered and sharp edges filed off smooth. Flame cutting will not be allowed.
5. All pipes and fittings will be laid or placed to the lines and grades shown on the Drawings with bedding and backfill shown on the Drawings and as specified in this Section.
6. No pipe will be laid until the QA/QC Manager has approved the bedding conditions.
7. No pipe will be brought into position until the preceding length has been bedded and secured in its final position.
8. Blocking under piping will not be permitted unless specifically required for special conditions.
9. The Contractor will provide all necessary adapters and/or connection pieces required when connecting different types and sizes of pipe or when connecting pipe made by different manufacturers.

3.04 JOINTS AND CONNECTIONS

A. HDPE pipes will be joined with thermal butt-fusion joints. All joints will be made in strict compliance with ASTM D2657 and the manufacturer's recommendations, and will be performed by manufacturer's authorized, trained fusion personnel.

B. Mechanical connections of HDPE pipe to auxiliary equipment such as valves, flow meters, pumps and tanks will consist of the following unless otherwise specified:
   1. An HDPE flange connection, called a stub end, will be butt-fused to the HDPE pipe. Outside diameter and drillings will comply with ANSI B16.1.
   2. A ductile iron back-up flange. Outside diameter and drillings will comply with ANSI B16.6.
   3. A flange of the convoluted design and cast from ductile iron. The flange will be marked with size, bolt hole template, material and type of flanges. The flange will mate with ANSI B16.5, B16.1, AWWA C207 and MSS-SP 43.
   4. Other mechanical couplings, such as 360 degree full circle clamps, will only be used if approved by the Engineer.

C. Polyethylene stub ends and flanges must be at the ambient temperature of the surrounding soil at the time they are bolted tight to prevent relaxation of the flange bolts and loosening of the joint due to thermal contraction of the polyethylene. Bolts will be drawn up evenly and in line.

3.05 TESTING OF HDPE PIPES AND FITTINGS

A. General:
   1. All non-perforated pipes and fittings that will be used to convey liquids will be hydrostatic tested prior to placing fill over the pipe.

   3. The Contractor will provide all testing apparatus, including pumps, hoses, gauges, taps, plugs, drains, temporary connections, and fittings, and will provide verification and results of gauge calibration prior to (less than 60 days) and after Project completion.
   4. All tests will be performed in the presence of the onsite QA/QC Manager.
   5. HDPE pipe with thermal butt-fusion type joints will be tested at 1½ times the working pressure.
   6. Test duration will be one hour, and pressure drop will not exceed 1%.
   7. The maximum length of tested pipe segment will not exceed 2000 feet.

B. Repair:
   1. Installed pipes that leak, according to the test results, will be either repaired to the satisfaction of the MCP or their designated representative or replaced at no cost to MCP. Repaired or replaced pipe will be successfully pressure-tested prior to filling over the pipe.
   2. Visible leaks will be repaired and retested.

C. Test Reporting:
   1. Report each test in writing including the following information if failure occurs:
      a. Location of failure segment;
      b. Nature of leaks;
      c. Details of repairs performed; and
      d. Retest results.

3.06 PRODUCT PROTECTION

A. The Contractor will use all means necessary to protect all prior work, including all materials and completed work of other Sections.

TABLE 02610-1
REQUIRED PROPERTIES
FOR HDPE PIPE MATERIAL

Properties	Qualifier	Units	Specified Value	Test Method
Density	between	g/cc	0.941 – 0.957	ASTM D1505
Melt Flow	maximum	g/min.	0.15	ASTM D1238, Condition E
Flexural Modulus	between	psi	110,000 – 160,000	ASTM D790
Tensile Strength at Yield	minimum	psi	3,200 – 5,000	ASTM D638
ECSR	minimum	hrs	5,000	ASTM D1693, Condition C
Pent	minimum	hrs	500 for PE 4710 or 100 for PE 3408	ASTM F1473
Hydrostatic Design Basis	minimum	psi	1,500 (@ 23° C	ASTM D2837

[END OF SECTION]

SECTION 02920
SEEDING

SECTION 02920

SEEDING

PART 1 GENERAL

1.01 SECTION INCLUDES

A. The Contractor will furnish all labor, materials, tools, supervision, transportation, and installation equipment necessary for seeding, mulching, fertilizing, and other incidental activities to establish grassy vegetation on the surface of the final cover system of the RCRA Subtitle C Cell and associated adjacent disturbed areas. The work includes preparing seedbed, applying fertilizer, seed, and mulch, and maintaining seed until successful germination and growth.

1.02 RELATED SECTIONS

A. Section 02300 – General Earthwork

1.03 CONSTRUCTION QUALITY ASSURANCE

A. Seeding activities, while not part of the formal CQA program, will be monitored by the QA/QC Manager.

1.04 EXISTING CONDITIONS

A. The Contractor will comply with applicable regulations in locating and providing clearance for all underground and above ground utilities prior to beginning construction activities.

PART 2 PRODUCTS

2.01 MATERIALS

A. The Contractor will furnish seed labeled in accordance with U.S. Department of Agriculture (USDA) Rules and Regulations under the Federal Seed Act and Texas Seed and Plant Certification Act and Standards. Each variety of seed will have a purity of not less than 90 percent, a percentage of germination not less than 80 percent, and a weed seed content of not more than 0.75 percent and will contain no noxious weeds. The above percentages are by weight.

B. The Seed Mix will be in accordance with the following:

PLANTING DATES	PLANT SPECIES	SEEDING RATE (pounds/acre)
October 1 to March 31	KY-31 Tall Fescue	15
	Common Bermudagrass (60% Hulled and 40% Unhulled, by weight)	50
	Gulf Annual Ryegrass	15
	Crimson Clover and Inoculant	20
April 1 to September 30	Foxtail Millet	15
	Common Bermudagrass (60% Hulled and 40% Unhulled, by weight)	60

Seeding Rate is for Pure Live Seed (PLS). PLS = (% germination + % dormant seed) x % purity.

C. Provide seed that complies with the referenced standards in this Section.

D. Provide seed in clean, unopened, undamaged bags with tags affixed for inspection in the field, including the date of expiration. Seed will not be used after its date of expiration. The Contractor will furnish seed from same or previous year's crop.

E. Provide seeds containing no objectionable material, such as sticks, stems and unthrashed seed heads, which will hinder proper distribution.

F. Seed that is wet, moldy, starting to germinate or otherwise damaged, will be considered nonconforming.

G. For dry application seeding:
   1. Areas requiring mulch will use mulch consisting of threshed straw of cereal grain such as oats, wheat, barley, rye, rice, etc., or grass hay, and will be free of clay, stones, foreign substances, plant parts of Canada Thistle and Johnson grass, and other weed seeds. All mulch applications must include a suitable form of mulch anchoring to minimize movement of mulch by wind or water (e.g., hydromulch, tackifier).
   2. Areas requiring erosion matting will use straw mat with plastic netting in accordance with the Texas Department of Transportation Class 1-Type C Approved Product List, Item 169 "Soil Retention Blanket."

H. For hydroseeding with mulch,
   1. Use a homogeneous aqueous mixture of seed, water, fertilizer, dye, wood fiber mulch, and tackifier). Apply tackifier at rates in accordance with manufacturer's recommendations, and apply hydroseed mixture at appropriate rate depending on slope, as specified herein.

I. Tackifier will be guar gum or equivalent biodegradable organic tackifier compound.

J. Fertilizer will be dry or liquid commercial grade fertilizer uniform in composition that meets the requirements of all State and Federal regulations and standards of the Association of Agricultural Chemists. Fertilizer will be delivered to the site in original, properly labeled, unopened, clean, containers each showing the manufacturer's guaranteed analysis conforming to applicable fertilizer regulations and standards. Fertilizer will be Grade 12-12-12, containing the specified percentages by weight of nitrogen (N), phosphate (P_2O_5) and potash (K_2O). A minimum of 50% of the nitrogen (N) will be slow release nitrogen or the fertilizer will be a complete formula. Apply fertilizer to all areas receiving seed.

PART 3 EXECUTION

3.01 FAMILIARIZATION

A. Prior to implementing any of the work described in this Section, the Contractor will inspect the installed work of all other Sections and verify that all work is complete to the point where the work of this Section may properly commence without adverse impact.

3.02 EROSION PROTECTION AND SEDIMENT CONTROL

A. Prior to implementing any of the work described in this Section, the Contractor will install all erosion protection and sediment control features.

B. Contractor will maintain all erosion protection and sediment control features throughout construction.

3.03 SEEDBED PREPARATION

A. Areas to be seeded will be prepared in accordance with the following: Loosen soil to a depth of about 4 inches by disking, harrowing, or other approved methods. Clods, loose stones, and other foreign material larger than 3 inches in any dimension will be removed and disposed of. Gullies, washouts, depressions, and other irregularities will be repaired before they are seeded.

3.05 APPLYING FERTILIZER

A. When dry fertilizer is used, it will be applied uniformly to the seeding areas at the time of seeding at a minimum rate of 100 lbs of nitrogen/acre (or as otherwise recommended by a Texas Certified Agronomist based on the results of the topsoil pre-construction tests specified in Section 02300) according to TxDOT Item 166 – Fertilizer. The method of application will be in accordance with manufacturer's instructions (e.g., disking, raking, harrowing, with hydroseeding).

B. When applied in liquid form or mixed with water, fertilizer will provide the same value of nutrients per acre as specified for dry fertilizer. Fertilizer applied in liquid form will be agitated during application.

3.06 APPLYING SEED

A. Regular seeding will consist of uniformly applying seed on prepared areas. Seeding may be applied by the dry seeding method (in conjunction with specified fertilizing and mulching/erosion matting), or by hydroseeding with mulch method. Regular seeding will also be performed in areas that are to be covered with erosion mats, unless other recommendations are made by the erosion mat manufacturer.

B. For dry application of seeding, plant seed with a broadcast spreader or culti-packer seeder. Plant seed no deeper than ¼ inch, with the distance between rows 12 inches or less, and uniformly distributed. Roll the planted seedbed with a culti-packer immediately after seeding and prior to applying mulch cover. Seed may be broadcast by hand for small areas inaccessible to seeding equipment. Apply mulch on seeded areas as described herein.

C. For hydroseeding with mulch, uniformly apply the homogeneous mixture of seed, water, fertilizer, dye, wood fiber mulch, and tackifier to the seedbed in accordance with manufacturer's recommendations and at the rates specified herein.

D. Temporary stabilization by seeding or other measures will be immediately initiated on any portion of the site where earth disturbing activities have temporary ceased and will not resume for a period exceeding 30 calendar days. Temporary stabilization must be completed no more than 14 calendar days after initiation of soil stabilization measures.

E. Permanent seeding will take place as soon as practicable after topsoil placement, but not later than 30 days. Long-term exposure of bare earth is not permitted.

F. Overseeding will consist of applying seed and fertilizer on areas previously vegetated. These areas will be mowed prior to overseeding. The soil surface will be lightly disked or harrowed. Culti-pack area to cover seed with ¼ inch of soil after overseeding.

G. Erosion controls may not be removed until the site is vegetated to 70% of the native background vegetative cover.

3.07 APPLYING MULCH

A. Dry seed application method:

1. On slopes flatter than ten (10) percent [10(horizontal): 1(vertical)], spread specified mulch material immediately after completion of seeding operation, at a rate of 2,000 pounds per acre.

2. On slopes equal to or steeper than ten (10) percent [10(horizontal): 1(vertical)]:

   a. Install erosion matting immediately after completion of seeding operation in accordance with manufacturer's installation recommendations; or

   b. Hydromulch immediately after completion of seeding operation at a rate of 3,000 lbs/acre.

B. Hydroseeding with mulch method:

1. On slopes flatter than ten (10) percent [10(horizontal): 1(vertical)], apply hydroseed with mulch mixture using a wood fiber mulch rate of 2,000 pounds per acre, blended with specified fertilizer application rate, seed mix, and tackifier rate in accordance with manufacturer's recommendations.

2. On slopes equal to or steeper than ten (10) percent [10(horizontal): 1(vertical)], apply hydroseed with mulch mixture using a wood fiber mulch rate of 3,000 pounds per acre, blended with specified fertilizer application rate, seed mix, and tackifier rate in accordance with manufacturer's recommendations.

C. Mulch will not be required on overseeded areas or on areas where erosion mats will be placed.

3.08 PROTECTION OF WORK

A. The Contractor will use all means necessary to protect the seeded areas and all prior work. Maintenance of the seeded areas includes repairing eroded areas, reseeding, watering, and mowing (if needed). A satisfactory condition of seeded area is defined as planted seed that has germinated, rooted in the soil, and is visibly growing above the surface of the topsoil into a good thick mowable stand of grass, with each 10,000 square feet section of turf that having no bare spots larger than three square feet and not more than 10 percent of the total area having bare spots larger than 6-inches square.

3.09 ACCEPTANCE

A. The seeded areas will be accepted at the end of the warranty period specified in 3.10A if a satisfactory condition as defined in this Section exists.

3.10 WARRANTY PERIOD

A. Seeded area will be subject to a warranty period of not less than 1 full growing season from initial establishment of vegetation over 100 percent of the areas seeded.

[END OF SECTION]

EXHIBIT 3
SLOPE STABILITY EVALUATION

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

SLOPE STABILITY ANALYSIS
MALONE SERVICE COMPANY SUPERFUND SITE

5/4/2015

STATE OF TEXAS
SCOTT M. GRAVES
86557
LICENSED PROFESSIONAL ENGINEER

SEALED FOR
CALCULATION PAGES 1
THROUGH 262

GEOSYNTEC CONSULTANTS, INC.
TX ENG. FIRM REGISTRATION NO. F-1182

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1 INTRODUCTION

1.1 Purpose

The purpose of this calculation package is to evaluate the slope stability of the proposed RCRA Subtitle C Cell (landfill) at the Malone Service Company Superfund Site (site) in Texas City, Texas. Analyses were performed along interim and final slopes which were developed based on critical combinations of slope geometry and soil shear strength properties. Slope stability factors of safety (FS) are evaluated herein for a variety of potential sliding failure scenarios.

1.2 Seismic Stability Requirements

A seismic impact zone is considered an area with a 10% or greater probability that the maximum horizontal acceleration (MHA) in lithified earth material exceeds 0.10g in 250 years. Values of MHA having a certain probability of exceedance (PE) are generally determined from United States Geologic Survey (USGS) National Seismic Hazard Maps. Current National Seismic Hazard Maps present MHA values for a seismic risk level of 2% probability that the MHA will be exceeded in 50 years (i.e., PE = 2% in 50 years); however, a seismic risk level of PE equals 2% in 50 years is approximately statistically equivalent to PE equals 10% in 250 years. According to the most recent (2014) USGS National Seismic Hazard Map, the MHA at the Malone site (29° 20' 5" N, 94° 54' 14" W) corresponding to PE equals 2% in 50 years is 0.04g (Figure 1). Therefore, the Malone site is not located in a seismic impact zone and does not require seismic stability analyses.

1.3 Method

The slope stability analyses were performed using a method of slices coded in the computer program SLIDE, Version 6.029 [Rocscience, 2014]. The computer program was used to generate circular and non-circular (block-type) shear surfaces and to calculate the factor of safety of these surfaces using Spencer's (1967) method.

1.4 Selection of Factors of Safety

The slope stability factor of safety (FS) is evaluated for cross sections that represent critical combinations of geometry and shear strength. Minimum acceptable factors of safety for landfill slope stability depend on project-specific conditions and uncertainties. The target calculated factor of safety using undrained strength parameters under interim conditions (i.e., perimeter dike slopes prior to liner system construction, liner system veneer, and interim landfill slopes during operation) is 1.25 in consideration of recommendations by Duncan (1992). The target calculated factor of safety using drained strength parameters under final conditions (i.e., final

cover veneer, final liner and foundation conditions, and final landfill slopes at the end of operation) is 1.5 (EPA, 2004). Note that the factors of safety recommended in the EPA Technical Guidance Document (2004) references Duncan (1992) which recommends considering the uncertainty of strength measurements and the consequences of failure into the factor of safety.

In contrast, for large-displacement cases considered herein with shear surfaces that pass along a liner or final cover system interface, target factors of safety were assigned and the minimum required large-displacement strengths producing the target factor of safety were back-calculated. That is, the large displacement strengths were iterated until the desired factor of safety was achieved. The target minimum calculated factor of safety using large-displacement strengths was set as 1.0 for interim conditions and 1.15 for final conditions. This approach is consistent with (for interim conditions) and more conservative than (for final conditions) that outlined in TCEQ's Industrial Solid Waste Management "Technical Guideline No. 3 – Landfills" (TCEQ, 2009) which recommends a factor of safety of 1.0 for residual strength (i.e. large displacement) conditions. The results of the back-calculation analysis were then incorporated into the Technical Specifications for the liner and final cover system materials.

1.5 Overview of the Subsurface Strata

Subsurface Conditions at Malone Service Company Superfund Site

The Preliminary Site Characterization Report (PSCR) (2004) describes the underlying soils at the site. In general, the subsurface soil is clay (CL or CH) with three non-contiguous transmissive zones of interbedded clay, sand, and silt (CL, SC, SM, or ML) mixtures (Figures 10-17 in Remedial Investigation (RI) (2006); included in Appendix 1.2).

- The upper zone (identified as TZ-1 in the PSCR) is about 10 feet below ground surface (bgs) and ranges in thickness from 0 to 8 feet.
- The second zone (TZ-2) is about 18 to 28 feet bgs, ranges in thickness from 0 to 12 feet, and consists of silty clay, silty sand, and silt.
- The deeper zone (TZ-3) is about 35 to 48 feet bgs, ranges in thickness from 0 to 14 feet, and consists of silt, silty sand, and sandy clay.

In addition to the three transmissive zones listed above, the PSCR describes the buried paleochannel, or sand channel, that meanders across the site (Figure 18 in RI (2006); included in Appendix 1.2). As shown on Figures 10-17 of the RI report (2006) (figures included in Appendix 1.2), the paleochannel is found about 10 feet bgs and is about 20 feet thick. It typically consists of tan, fairly uniform, very fine-grained, silty sand.

Comparison to Subsurface Conditions at Gulf Coast Waste Disposal Authority Campbell Bayou Facility (CBF)

The Campbell Bayou Facility (CBF) is located directly adjacent to the western boundary of the Malone Superfund site and has had various subsurface investigations performed that provide relevant and useful data that can be applied to the Malone Superfund Site. Existing data from the CBF (cross sections and laboratory data from Geosyntec (2008) are included in Appendix 1.3 and 2, respectively) is used to correlate the CBF subsurface soils to the Malone Superfund Site subsurface soils.

As shown on the CBF cross-sections (Appendix 1.3), it is evident that the previously conducted analysis of the subsurface conditions at this adjacent site is in agreement with that of the Malone site. For clarification, the stratum nomenclature varies. For the Malone site, in the PCSR (2004), the clay zones of the subsurface were not assigned a unique nomenclature. Instead, only the transmissive zones at the Malone site were assigned specific naming designations in the PCSR. For the CBF, the subsurface was divided into layers referred to as Stratum I through Stratum V (starting at the ground surface). At the CBF, the underlying clay was separated into layers referred to as Strata I, III, and V while the underlying sand zones were primarily Stratum II and Stratum IV (along with discontinuous portions of Stratum III).

For this slope stability analysis, the nomenclature established for the CBF will be applied to the Malone site. This is based on an evaluation of the similarity of the layers (e.g., depths/thicknesses, material properties) between the two sites and how they correlate. This allows the properties assigned to strata beneath the CBF to also be used for the corresponding strata beneath the Malone site. With respect to the transmissive zones, the Malone names are correlated to the CBF names as follows:

- TZ-1 of the Malone PCSR correlates to Stratum II at the CBF;
- TZ-2 of the Malone PCSR correlates to the discontinuous silt lens within Stratum III at the CBF; and
- TZ-3 of the Malone PCSR correlates to Stratum IV at the CBF.

Additionally, it is noted that a buried sand channel that is generally about 10 feet bgs and about 20 feet thick was found underneath the CBF site as shown on Figure R-19 in Appendix 1.3. According to Figure 5 in Appendix 1.1 (PSCR, 2004), this is believed to be the same paleochannel feature that crosses the Malone Superfund Site.

Comparison of Material Properties

Given that the Malone and CBF sites are directly adjacent to each other and that the cross-sections for each site demonstrate consistency of the strata types/thicknesses/properties, this slope stability analysis was supplemented with the available geotechnical data from the CBF.

Naming Convention

The soil strata are more clearly identified and differentiated in the CBF (Geosyntec, 2008) report, and a thorough geotechnical testing program was conducted within these soil layers. Therefore, the CBF naming convention shown below for the subsurface soils is used for this slope stability evaluation for the soils at the Malone site. Where applicable, the transmissive zones (TZs) identified in the Malone PCSR are noted.

- Stratum I is the shallow clay layer;
- Stratum II is the interbedded shallow silt and sand layer (TZ-1);
- Stratum IIa is the buried sand channel;
- Stratum III is the lower clay layer with interbedded silt lenses (TZ-2);
- Stratum IV is the lower silt layer (TZ-3); and
- Stratum V is the deep clay layer.

2 CRITICAL CROSS SECTIONS

The slope stability analysis was performed for several cross sections to evaluate the various critical configurations of the landfill for the various applicable sliding modes at those sections. Critical cross sections for analyses were chosen based on consideration of critical combinations of geometry and soil properties. The following information was considered:

- The overall liner subgrade grading plan (Figure 2)
- The overall top of final cover grading plan (Figure 3)
- Geologic sections prepared by URS (Appendix 1.1 and 1.2) and by Geosyntec (Appendix 1.3);
- The approximate boundary of the paleochannel (Figure 5 in Appendix 1.1, Figure 18 in Appendix 1.2, and Figure R-19 in Appendix 1.3); and
- Potentiometric surfaces (Figures 20-23 in Appendix 1.2).

The liner subgrade grading plan and top of final cover grading plan with the locations of cross sections are shown on Figures 2 and 3 of this calculation package, respectively.

As shown on the figures, Section A is oriented length-wise through the middle of the landfill, Section B is oriented width-wise through the middle portion of the landfill, Section C is oriented width-wise through the northeast portion of the landfill, and Section D is oriented north-south through the north portion of the landfill. The cross sections, as modeled in SLIDE, are shown on Figures 4 through 7. The slopes analyzed are as summarized in Sections 2.1 through 2.4 below.

2.1 Liner System and Final Cover System

Veneer is a term that refers to the constructed liner system layers and the constructed final cover system layers. The critical cross section for evaluation of a liner system veneer is with the installed liner system on the longest 3H:1V slope. The final cover slopes vary, but the critical cross section for the final cover system veneer is for the 7H:1V final cover slope which is the steepest slope of the final cover. Shear strengths used in the veneer stability analysis of the liner system and final cover system were based on both short-term (undrained) and long-term (drained) conditions.

2.2 Levee and Berm Slopes

This case refers to the stability of the levee and the compacted earthen berm around the landfill prior to waste placement (i.e. when the levee and berm are un-buttressed by waste). As shown on the Figures 4 through 7, the levee slopes vary while the earthen berm incorporates 3 horizontal to 1 vertical (3H:1V) external and internal slopes. The steeper and more critical portions of the levee and the 3H:1V berm slopes (Figure 8) were analyzed for both short-term and long-term stability assuming circular and block slip surfaces. Although these slopes are expected to be short term conditions, the long term stability analysis is important to account for the scenario in which waste placement is delayed for a period of time that is sufficient to allow soil drainage of the foundation and levee or berm, while leaving the slopes un-buttressed.

2.3 Interim Landfill Slope

This case refers to the stability of interim landfill conditions as waste placement progresses during landfill operations. The solidified sludge waste is expected to be placed in lifts that have relatively shallow slopes (5.5% or less) due to the relatively low laboratory-measured strength of the material, as discussed in Section 4.3 of this report. The lower strength waste will be buttressed against an interphase berm which will be constructed of the higher strength impacted soils (or structural fill soil). Therefore, the critical case analyzed for stability of the interim landfill slope is when the lower strength solidified sludge waste has reached its maximum height and is buttressed against the maximum height of the higher strength impacted soils (Figure 9). This is will likely be a short term (undrained) condition, but the final (drained) condition was

also analyzed. It is noted that this section was also used to back-calculate minimum interface shear strengths of the liner system materials.

2.4 Final Landfill Slopes

This case refers to the stability of the overall landfill (including the levee, berm, waste mass, and foundation) when constructed to final conditions. It is also noted that a special case was considered in the stability analyses to account for the recent remediation activities at the Malone site. As part of these activities, a soil-bentonite slurry wall has been installed around the earthen impoundment area (Figure 2 in Appendix 1.2). The slurry wall that surrounds this area is approximately three feet wide and 40 feet deep. However, it is noted that the slurry wall was conservatively assumed to extend vertically through the entire thickness of the analyzed cross section. Therefore, the critical cases analyzed for stability of the final landfill slopes are:

- the slope where the final cover landfill slopes will be the steepest (Figure 5);
- the slope where the length along the liner system will be the longest (Figure 6); and
- the slope where the landfill will be in closest proximity (approximately ten feet from the outer toe of the perimeter berm) to the soil-bentonite slurry wall (Figure 7).

3 LINER SYSTEM AND FINAL COVER SYSTEM MATERIALS

3.1 Liner System

The liner system for the Malone Service Company site consists of the following components, from top to bottom:

- 1-foot (ft.) thick protective cover soil layer (impacted soils);
- geocomposite drainage layer (single- or double-sided);
- 80-mil HDPE geomembrane (smooth or textured);
- geonet or double-sided geocomposite;
- 80-mil HDPE geomembrane (smooth or textured);
- geosynthetic clay liner (GCL); and
- 1-ft thick compacted clay.

3.2 Final Cover System

The final cover system cross section consists of the following components from top to bottom:

- grassy vegetation;
- 6-inch (in.) thick vegetative layer;
- 1-ft thick cover soil layer;

- geocomposite drainage layer (single- or double-sided);
- 40-mil LLDPE geomembrane (smooth or textured);
- geosynthetic clay liner (GCL); and
- double sided geocomposite (gas vent layer).

It is noted that for these stability analyses, the minimum required interface friction angles along the weakest interface of the liner and final cover systems were back-calculated to achieve the target factors of safety. Therefore, the analysis does not limit the geomembrane to textured (or smooth), nor does it limit the type of other geosynthetics, as long as the minimum interface friction angles are met or exceeded.

4 MATERIAL PROPERTIES

Selected material properties for the site soils are based on site investigations previously performed at the adjacent Campbell Bayou Facility (CBF). Soil borings at CBF were completed from 1976-2008 by various companies including Southwestern Laboratories; Law Engineering Testing Company; Harding Lawson Associates; McCulley, Frick & Gilman, Inc.; ENSR; Fugro Geosciences, Inc.; HTS, Inc.; and Geosyntec Consultants.

Laboratory tests relevant to these analyses that were conducted as part of one or more of these investigations include: grain size analysis and/or percent passing No. 200 sieve, Atterberg limits, USCS soil classification, moisture content, dry unit weight, direct shear, unconsolidated undrained, and consolidated undrained. Table 1 summarizes the properties of all materials used in this analysis (select lab results are included in Appendix 2).

4.1 Soil Unit Weights

The unit weights for all of the soil strata are summarized in Table 1. Based on the referenced laboratory results, total unit weights were calculated for each soil stratum (Table 2) and average measured values from these calculations were used in the analysis for Stratum I through V. Also, typical values from Duncan et al. (1989) (Table 3) were used to estimate a unit weight of 125 pcf for the sand paleochannel (Stratum IIa) and 120 pcf for the levee, berm, cover soil, and other fill material.

4.2 Soil Shear Strengths

Foundation Soils - Undrained Strength. The undrained shear strengths of Stratum I through V were selected based on the results of unconfined compression tests and unconsolidated undrained triaxial shear strength tests reported in Appendix 2 and are summarized in Table 1. It is noted

that the sand paleochannel is expected to exhibit drained behavior and is accordingly assigned drained strength properties in the slope stability analysis as discussed subsequently.

Foundation Soils – Drained Strength. The drained shear strengths of Stratum I through V were selected based on the results of consolidated undrained triaxial shear strength tests and direct shear tests reported in Appendix 2. For Stratum I, III, and V, the effective stress cohesion and friction angle assumed in the analysis are c' = 430 psf and φ' = 13.2°, respectively. For Stratum II and IV, the effective stress cohesion and friction angle assumed in the analysis are c' = 575 psf and φ' = 18.3°. For the sand paleochannel (Stratum IIa), historical borings indicate that these soils are generally firm and have SPT blow counts averaging about 14 blows per foot. As indicated in Table 4, Holtz et al. (2011) recommends a friction angle of 30 – 35 degrees for clayey sands with these properties. For added conservatism, a friction angle of 25 degrees was used for the sand paleochannel in the analysis.

Levee, Berm, Fill and Protective Cover (Final Cover System). In general, compacted clay was used for the levee and will also be used for the berm surrounding the landfill as well as for fill material. Additionally, it is expected that surficial site soils will be used for the final cover system protective cover; however, since the soil will need to be excavated before being placed as protective cover, the fill properties are used for this layer as well. For these soils, typical strength properties of compacted clay from Duncan et al. (1989) (Table 3) were used in the slope stability analyses (Table 1).

Interface Shear Strength – Liner and Final Cover. The liner and final cover will have geosynthetic and soil components. Typical values of shear strength for common geosynthetic and soil interfaces are presented in Table 5.

Slurry Wall. As discussed in Section 2.4, a slurry wall has been constructed in the earthen impoundment area adjacent to the landfill perimeter. Soil-bentonite slurry walls generally have low strength, so the slurry wall is modeled in the analysis as having a unit weight of 90 pcf and zero strength.

4.3 Waste Properties

The Malone Superfund site will dispose of impacted soil and solidified sludge waste within the landfill. The properties selected for use in the analyses are detailed below.

Waste – Impacted Soil. Impacted surficial soil will be excavated from different parts of the site. As shown on Figure 14 of Appendix 1.4, the depth of excavation varies from about two feet in some areas to about ten to fifteen feet in other areas. Accordingly, the material properties are expected to be similar to Stratum I and II. Therefore, the material properties were selected as follows: (1) a unit weight of 120 pcf; (2) an undrained strength of Su = 750 psf; and (3) a drained

strength of c' = 450 psf and φ' = 15°. It is noted that impacted soil waste will also be used for the liner system protective cover. For conservatism, the material properties of this material on the liner system were selected as follows: (1) a unit weight of 120 pcf; (2) an undrained strength of Su = 750 psf; and (3) a drained strength of c' = 250 psf and φ' = 15°.

Waste – Sludge. Standard Proctor tests conducted on three samples of waste are attached in Appendix 2. Based on the Proctor tests, the total unit weight of the waste is about 90 pcf and is assigned to the sludge waste for these analyses. The consistency of the solidified waste is silty sand with some clay. The waste is assumed to exhibit drained conditions based on the relatively high laboratory-measured hydraulic conductivity values (see Appendix 2); therefore, the material is assumed to dissipate pore water pressures quickly enough to exhibit drained conditions. The effective stress shear strength properties were also measured in a laboratory. Direct shear testing of waste samples involved shearing the samples in a water bath at a rate of 0.02 inches per minute (in/min). It is noted that these testing conditions are conservative because the waste mass in the landfill is not expected to be saturated with water nor is it expected to experience shearing at the rate conducted in the laboratory. The lowest measured effective stress strength envelope (c' = 0 psf and φ' = 5 degrees) from the direct shear testing was used in this analysis, though the testing conditions are believed to have resulted in conservatively low measured strengths.

5 RESULTS AND CONCLUSIONS

The critical cases of landfill stability are discussed in this section. Full results are presented in Appendix 3 and 4 and are summarized in Tables 6 through 10 as follows:

- Table 6: the liner system and final cover system veneer stability (Section 2.1);
- Table 7: the levee slopes (Section 2.2);
- Table 8: the berm slopes (Section 2.2);
- Table 9: the interim landfill slopes (Section 2.3); and
- Table 10: the final landfill slopes (Section 2.4).

5.1 Liner System and Final Cover System Veneer

The veneer stability of the liner system was analyzed for various cases (presented in Appendix 3 and 4; summarized in Table 6). The most critical case is expected to occur when the solidified sludge waste has reached final waste height and is buttressed against the interphase berm which will be constructed of impacted soils with 2H:1V slopes. The slip surface for this scenario is through the liner system components and the waste mass. For target minimum calculated factors of safety of 1.25 and 1.0, the peak and large displacement back-calculated interface friction angle are δ_{peak} = 8.6° and $\delta_{large\ displacement}$ = 4.8°. Extensive research has been conducted on the shear strength of various interfaces; Table 5 provides a summary of the range of expected values.

According to Table 5, the back-calculated interface friction angle for peak and large displacement conditions is on the lower bound of achievable shear strength. However, these back-calculated strength parameters should be specified as technical specifications for the selected liner system components and should be verified with laboratory testing.

The veneer stability of the final cover system was also analyzed (Appendix 3). The final cover slopes are generally shallow with only 1.5-ft of overburden material applying a load on the geosynthetics; therefore, for this scenario, the results of the veneer stability model indicate that there is no required interface shear strength for the final cover system geosynthetics. However, for prudency, textured geomembrane is recommended on steeper slopes of the final cover (e.g. for slopes that are greater than or equal to 5.5%).

5.2 Levee and Berm Slope

The levee is an existing feature and the earthen berm will be constructed. It is noted that the stability analyses of the final landfill conditions includes slip surfaces that pass through the levee and berm; however, the standalone slopes were analyzed as well (presented in Appendix 4; summarized in Tables 7 and 8). The levee is taller and is more critical; under drained conditions, a non-circular slip surface through the full levee slope results in a factor of safety of 2.4. This critical case is still well above the target minimum calculated factor of safety of 1.25.

5.3 Interim Landfill Slope

The evaluated shear surface scenarios and factors of safety for the interim landfill slope outlined in Section 2.3 are summarized in Table 9. The critical case analyzed is an undrained analysis with a circular slip surface through the full waste slope and seated in Stratum II; the calculated factor of safety is 1.9 which is greater than the target minimum calculated factor of safety of 1.25 for interim conditions.

Additionally, the calculated minimum interface shear strength of the liner system – to achieve the target minimum calculated factor of safety (Section 1.4) – was evaluated for this interim slope (discussed in Section 5.1; summarized in Table 6).

5.4 Final Landfill Slope

The evaluated shear surface scenarios and factors of safety for the final landfill slope outlined in Section 2.4 are summarized in Table 10. The critical case analyzed is a drained strength analysis with non-circular slip surface through and seated in the waste mass; the calculated factor of safety is 1.8 which is greater than the target minimum calculated factor of safety of 1.5 for final conditions.

Furthermore, the calculated minimum interface shear strength of the liner system – to achieve the target minimum calculated factor of safety (Section 1.4) – was evaluated for the steepest landfill slope and found to be less critical than the interim landfill slope (Table 6).

5.5 Conclusions

Based on the discussion and analyses presented herein, it is highlighted that:

- critical cross sections were selected for analysis and that various modes of sliding were considered;
- soil and waste properties were selected based on conservative interpretations of the available laboratory data and published technical literature;
- the calculated factors of safety are all greater than or equal to the target minimum calculated factors of safety; and
- minimum required peak and large displacement interface shear strengths of the liner system and final cover system were back-calculated to achieve the target minimum calculated factor of safety.

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TABLES

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TABLE 1
SUMMARY OF MATERIAL PROPERTIES FOR SLOPE STABILITY ANALYSIS

Stratum/ Material	Soil Type	γ (pcf)	Undrained Shear Strength	Drained Shear Strength	
			Su (psf)	c' (psf)	φ' (degrees)
Cover	Clay/Geosynthetics	120	1000	250	20
Waste - Sludge		90	-	0	5
Waste – Impacted Soil		120	750	450	15
Liner	Protective Cover Geosynthetics Clay Liner	120	750	250	15
Levee/Berm/Fill	Clay	120	1000	250	20
I	Clay	128	1525	430	13.2
II	Silty Clay	127	760	575	18.3
IIa	Sand	125	-	0	25
III	Clay	124	1630	430	13.2
IV	Silt, Silty Sand, and Sandy Clay	124	1535	575	18.3
V	Clay	112	1615	430	13.2
Slurry Wall	Soil Bentonite	90	0	0	0
Liner and Final Cover Interface			$\delta_{interface}$ back-calculated		

Note:

γ = moist unit weight; Su = total stress cohesion;
c' = effective stress cohesion; φ' = effective stress friction angle

1. Properties for similar soils, Stratum I, III, and V assumed to be the same
2. Properties for similar soils, Stratum II, and IV assumed to be the same

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TABLE 2
SUMMARY OF SOIL UNIT WEIGHT MEASUREMENTS

Boring ID	Sample Depth (ft)	Stratum	Water Content (%)	Dry Unit Weight (pcf)	Total Unit Weight (pcf)
GB2	4-6.5	I - Shallow Clay	19.7	108.1	129.4
GB2	6.5-9	I - Shallow Clay	17.7	111.5	131.2
GB3	4-6.5	I - Shallow Clay	21.1	105.7	128.0
GB4	6-8.5	I - Shallow Clay	16.6	111.6	130.1
GB6	2-4.5	I - Shallow Clay	17.6	110.7	130.2
GB7	6-8.5	I - Shallow Clay	21.5	107.7	130.9
CX1	12-14	I - Shallow Clay	24	100	124.0
CX2	6-8	I - Shallow Clay	17	115	134.6
CX3	2-4	I - Shallow Clay	32	93	122.8
CX3	6-8	I - Shallow Clay	26	98	123.5
CX3	8-10	I - Shallow Clay	18	110	129.8
CX4	4-6	I - Shallow Clay	21	107	129.5
CX4	8-9	I - Shallow Clay	20	110	132.0
1	2-4	I - Shallow Clay	9.8	108.0	118.6
1	6-8	I - Shallow Clay	20.6	103.2	124.5
2	0-2	I - Shallow Clay	18.2	91.0	107.6
2	2-4	I - Shallow Clay	13.2	122.1	138.2
2	4-6	I - Shallow Clay	23.4	103.0	127.1
2	6-7.5	I - Shallow Clay	21.0	106.4	128.7
3	4-6	I - Shallow Clay	20.4	105.0	126.4
3	6-8	I - Shallow Clay	18.7	109.2	129.6
3	8-10	I - Shallow Clay	17.3	115.4	135.4
3	13-15	I - Shallow Clay	29.2	101.8	131.5
4	2-4	I - Shallow Clay	26.4	103.8	131.2
4	4-6	I - Shallow Clay	14.9	118.7	136.4
4	6-8	I - Shallow Clay	26.4	97.0	122.6
GB3	10.8-11.1	II - Shallow Silt	27.2	101.6	129.2
GB3	11.1-12.4	II - Shallow Silt	27.0	97.5	123.8
GB6	12.5-15	II - Shallow Silt	28.2	91.8	117.7
GB10	9-11.5	II - Shallow Silt	22.2	93.5	114.2
CX1	15.5-16	II - Shallow Silt	12	124	138.9
1	8-9.5	II - Shallow Silt	20.6	103.2	124.5
2	8-10	II - Shallow Silt	21.3	111.1	134.8
4	8-9.5	II - Shallow Silt	18.3	113.1	133.8
GB2	19-20	III - Lower Clay	32.4	94.6	125.3
GB2	19-21.5	III - Lower Clay	29.5	93.4	121.0

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Boring ID	Sample Depth (ft)	Stratum	Water Content (%)	Dry Unit Weight (pcf)	Total Unit Weight (pcf)
GB3	14-16.5	III - Lower Clay	28.4	94.8	121.7
GB3	24.5-27	III - Lower Clay	19.5	106.2	126.9
GB3	15-17.5	III - Lower Clay	28.1	93.7	120.0
GB3	27.5-30	III - Lower Clay	21.4	103.8	126.0
GB6	23-25.5	III - Lower Clay	28.8	94.2	121.3
GB6	33-35.5	III - Lower Clay	23.7	101.1	125.1
CX1	23-25	III - Lower Clay	32	93	122.8
CX1	28-30	III - Lower Clay	29	97	125.1
CX2	18-20	III - Lower Clay	32	90	118.8
CX2	23-25	III - Lower Clay	25	102	127.5
CX3	14-16	III - Lower Clay	22	104	126.9
CX4	23-25	III - Lower Clay	34	89	119.3
1	18-20	III - Lower Clay	31.0	92.8	121.6
1	23-25	III - Lower Clay	32.4	90.0	119.2
2	38-40	III - Lower Clay	23.8	105.6	130.7
3	18-20	III - Lower Clay	32.5	91.8	121.6
3	23-25	III - Lower Clay	32.7	91.7	121.7
3	28-30	III - Lower Clay	25.2	100.7	126.1
3	33-35	III - Lower Clay	28.1	98.0	125.5
3	38-40	III - Lower Clay	28.2	97.0	124.4
4	13-15	III - Lower Clay	29.9	95.3	123.8
4	33-35	III - Lower Clay	27.0	97.0	123.2
GB6	43.5-46	IV - Lower Silt	27.2	93.3	118.7
GB7	44.5-47	IV - Lower Silt	25.4	100.5	126.0
CX4	43-45	IV - Lower Silt	31	93	121.8
1	48-50	IV - Lower Silt	14.2	114.1	130.3
2	43-45	IV - Lower Silt	28.0	95.8	122.6
3	48.5-49.5	IV - Lower Silt	29.4	95.5	123.6
4	43-45	IV - Lower Silt	30.0	97.4	126.6
3	53-55	V - Deep Clay	35.1	86.4	116.7
3	58-60	V - Deep Clay	47.7	75.7	111.8
3	63-65	V - Deep Clay	50.2	72.3	108.6
3	68-70	V - Deep Clay	53.0	69.4	106.2
3	74-75	V - Deep Clay	33.4	87.8	117.1

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TABLE 3
TYPICAL PROPERTIES OF COMPACTED SOILS
(DUNCAN ET AL., 1989)

USCS	Soil Type	Maximum Dry Unit Weight	Optimum Moisture Content	Typical Strength Characteristics			
				Drained		Undrained	
		pcf	%	c' (psf)	φ' (deg)	c (psf)	φ (deg)
SP	Poorly graded clean sand, sand-gravel mixtures	110 ± 1	12.4 ± 1.0	0	37 ± 1	0	37-44
CL	Inorganic clays of low to medium plasticity	108 ± 1	17.3 ± 3.0	285 ± 40	28 ± 2	2100 ± 320	1-3
CH	Inorganic clays of high plasticity	94 ± 2	25.5 ± 1.2	245 ± 120	19 ± 5	1800 ± 980	0-2

Note:
1. USCS = Unified Soil Classification System

TABLE 4
TYPICAL PROPERTIES OF CLAYEY SANDS
(HOLTZ ET AL., 2011)

Relative Density Descriptors	SPT N (blows / 300 mm)	Friction Angle, φ' (degrees)
Very Loose	< 4	< 25
Loose	4 – 10	25 – 30
Medium	10 – 30	30 – 35
Dense	30 – 50	35 – 40
Very Dense	> 50	> 40

TABLE 5
SUMMARY OF DOCUMENTED INTERFACE FRICTION VALUES

GEOSYNTHETIC / GEOSYNTHETIC	δ_p [1] (°)	δ_{ld} [1] (°)
Smooth HDPE Geomembrane / Nonwoven Geotextile	7 - 12	6 - 11
Smooth LLDPE Geomembrane / Nonwoven Geotextile	10 - 12	
Textured HDPE Geomembrane / Nonwoven Geotextile	22 - 35	
Smooth HDPE Geomembrane / Geonet	7 - 15	
Textured HDPE Geomembrane / Geonet	7 - 16	10 - 12
Textured HDPE Geomembrane / Geocomposite	17 - 29	13 - 20
Geonet / Nonwoven Geotextile	13 - 22	
Smooth HDPE Geomembrane / GCL (hydrated)	8 - 12	
Textured HDPE Geomembrane / GCL (hydrated)	18 - 37	6 - 10
GEOSYNTHETIC / SOIL	**$\tan\delta_p/\tan\phi_p$ [1]**	**$\tan\delta_{ld}/\tan\phi_{ld}$ [1]**
Smooth HDPE Geomembrane / Clay	0.4 - 0.7	0.3 - 0.7
Textured HDPE Geomembrane / Clay	0.8 - 0.9	0.6 - 0.9
Smooth HDPE Geomembrane / Sand	0.5 - 0.6	
Textured HDPE Geomembrane / Sand	0.7 - 0.8	
Needlepunched Nonwoven Geotextile / Sand	0.8 - 1.0	
Needlepunched Nonwoven Geotextile / Angular Gravel	0.7 - 0.9	
Needlepunched Nonwoven Geotextile / Rounded Gravel	0.6 - 0.8	

Note: δ = interface friction angle; ϕ = soil internal friction angle; subscript p = peak; subscript ld = large displacement; table is adapted from tests by Martin et al. (1984), Williams and Houlihan (1986), Koerner et al. (1986), Williams and Houlihan (1987),Williams and Luna (1987), Eid and Stark (1997), Sabatini et al. (1998), Stark et al. (1998), manufacturer's literature, and unpublished results from Geosyntec Consultants.

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TABLE 6
SUMMARY OF VENEER STABILITY RESULTS FOR LINER AND FINAL COVER

Veneer Stability Shear Surface Scenario	Backcalculated interface friction angle[1]	Target Minimum Calculated Factor of Safety
Liner System		
Scenario: end of liner system construction prior to waste placement. 1-ft thick cover soil: confining pressure on geosynthetics = 120 psf. 3:1 slope: 30-ft long, 10-ft high. See Appendix 3.	δ_{peak} = 8.3°	1.25
	$\delta_{large\ disp}$ = 3.6°	1.0
Scenario: interim landfill slope – solidified sludge waste has reached maximum waste height and is buttressed against interphase berm; interphase berm is constructed of impacted soil with 2:1 sideslopes. Failure surface is through waste and seated in liner. 20-ft thick waste overburden on liner: approximate confining pressure on geosynthetics = 1,800 psf.	δ_{peak} = 8.6°	1.25
	$\delta_{large\ disp}$ = 4.8°	1.0
Scenario: final landfill slope – end of landfill construction. Full waste height: approximate confining pressure on geosynthetics = 1,800 psf.	δ_{peak} = 4°	1.5
	$\delta_{large\ disp}$ = 3°	1.15
Final Cover System		
Scenario: end of final cover system construction. 1.5-ft thick cover soil: confining pressure on geosynthetics = 180 psf. 7:1 slope: 70-ft long, 10-ft high. See Appendix 3.	δ_{peak} = 0.0°	1.5
	$\delta_{large\ disp}$ = 0.0°	1.15

[1] Backcalculated values are obtained from analyses presented in Appendix 3 and 4.

TABLE 7
SUMMARY OF SLIDE RESULTS FOR LEVEE SLOPE

Levee Slopes (Figure 8 - Top) Shear Surface Scenario	Calculated Factor of Safety (✓ if ≥ Target)	Target Minimum Calculated Factor of Safety
Undrained Conditions		
Undrained circular slip surface through full levee slope; seated in Stratum II	2.96 ✓	1.25
Undrained non-circular slip surface through full levee slope; seated in Stratum II	2.75 ✓	1.25
Drained Conditions		
Drained circular slip surface through full levee slope; seated in Stratum I	2.49 ✓	1.25
Drained non-circular slip surface through full levee slope; seated in Stratum I	2.43 ✓	1.25

TABLE 8
SUMMARY OF SLIDE RESULTS FOR BERM SLOPE

Berm 3H:1V Slopes (Figure 8 - Bottom) Shear Surface Scenario	Calculated Factor of Safety (✓ if ≥ Target)	Target Minimum Calculated Factor of Safety
Undrained Conditions		
Undrained circular slip surface through full berm slope; seated in Stratum II	9.33 ✓	1.25
Undrained non-circular slip surface through full berm slope; seated in Stratum II	5.31 ✓	1.25
Drained Conditions		
Drained circular slip surface through full berm slope; seated in Stratum I	5.08 ✓	1.25
Drained non-circular slip surface through full berm slope; seated in berm	5.37 ✓	1.25

TABLE 9
SUMMARY OF SLIDE RESULTS FOR INTERIM LANDFILL SLOPE

Interim Landfill Slopes (Figure 9) Shear Surface Scenario	Calculated Factor of Safety (✓ if ≥ Target)	Target Minimum Calculated Factor of Safety
Scenario: Undrained Condition – Landfill Slope after Reaching Maximum Waste Height with Interphase Berm		
Undrained circular slip surface through full waste slope; seated in Stratum II	1.91 ✓	1.25
Undrained non-circular slip surface through full waste slope; seated in liner	2.35 ✓	1.25
Scenario: Drained Condition – Landfill Slope after Reaching Maximum Waste Height with Interphase Berm		
Drained circular slip surface through full waste slope; seated in Stratum I	1.97 ✓	1.25
Drained non-circular slip surface through full waste slope; seated in liner	2.06 ✓	1.25

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TABLE 10
SUMMARY OF SLIDE RESULTS FOR FINAL LANDFILL SLOPE

Final Landfill Slopes Shear Surface Scenario	Calculated Factor of Safety (✓ if ≥ Target)	Target Minimum Calculated Factor of Safety
Undrained Conditions		
Section B (Figure 5): Undrained circular slip surface through full waste slope; seated in Stratum II	3.58 ✓	1.5
Section B (Figure 5): Undrained non-circular slip surface through full waste slope; seated in liner and berm	6.33 ✓	1.5
Section C (Figure 6): Undrained circular slip surface through full waste and levee slope; seated in Stratum II	2.70 ✓	1.5
Section C (Figure 6): Undrained circular slip surface through full waste and levee slope; seated in levee	5.52 ✓	1.5
Section D (Figure 7): Undrained circular slip surface through partial waste slope; seated in waste	2.45 ✓	1.5
Section D (Figure 7): Undrained non-circular slip surface through full waste slope; seated in waste	2.09 ✓	1.5
Drained Conditions		
Section B (Figure 5): Drained circular slip surface through full waste slope; seated in Stratum III	3.54 ✓	1.5
Section B (Figure 5): Drained non-circular slip surface through full waste slope; seated in liner and berm	4.55 ✓	1.5
Section C (Figure 6): Drained circular slip surface through full levee slope; seated in Stratum I	2.67 ✓	1.5
Section C (Figure 6): Drained non-circular slip surface through full levee slope; seated in Stratum I	2.90 ✓	1.5
Section D (Figure 7): Drained circular slip surface through partial waste slope; seated in waste	1.90 ✓	1.5
Section D (Figure 7): Drained non-circular slip surface through full waste slope; seated in waste	1.83 ✓	1.5

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FIGURES

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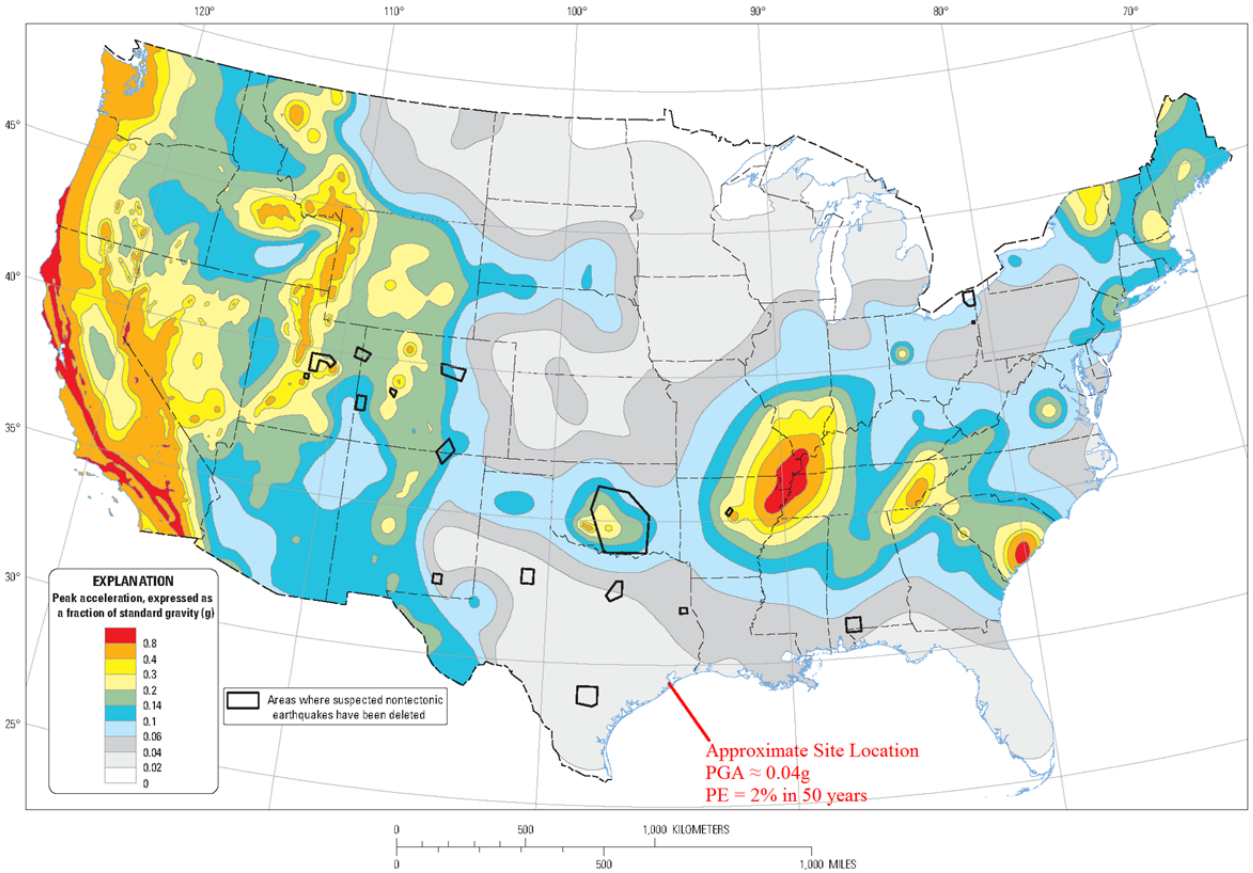


Figure 1: Seismic Hazard Map.

This USGS figure demonstrates that the Malone Service Company Superfund Site is geographically located in an area that has a 2% probability that a peak ground acceleration (PGA) of 0.04g will be exceeded in 50 years.

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

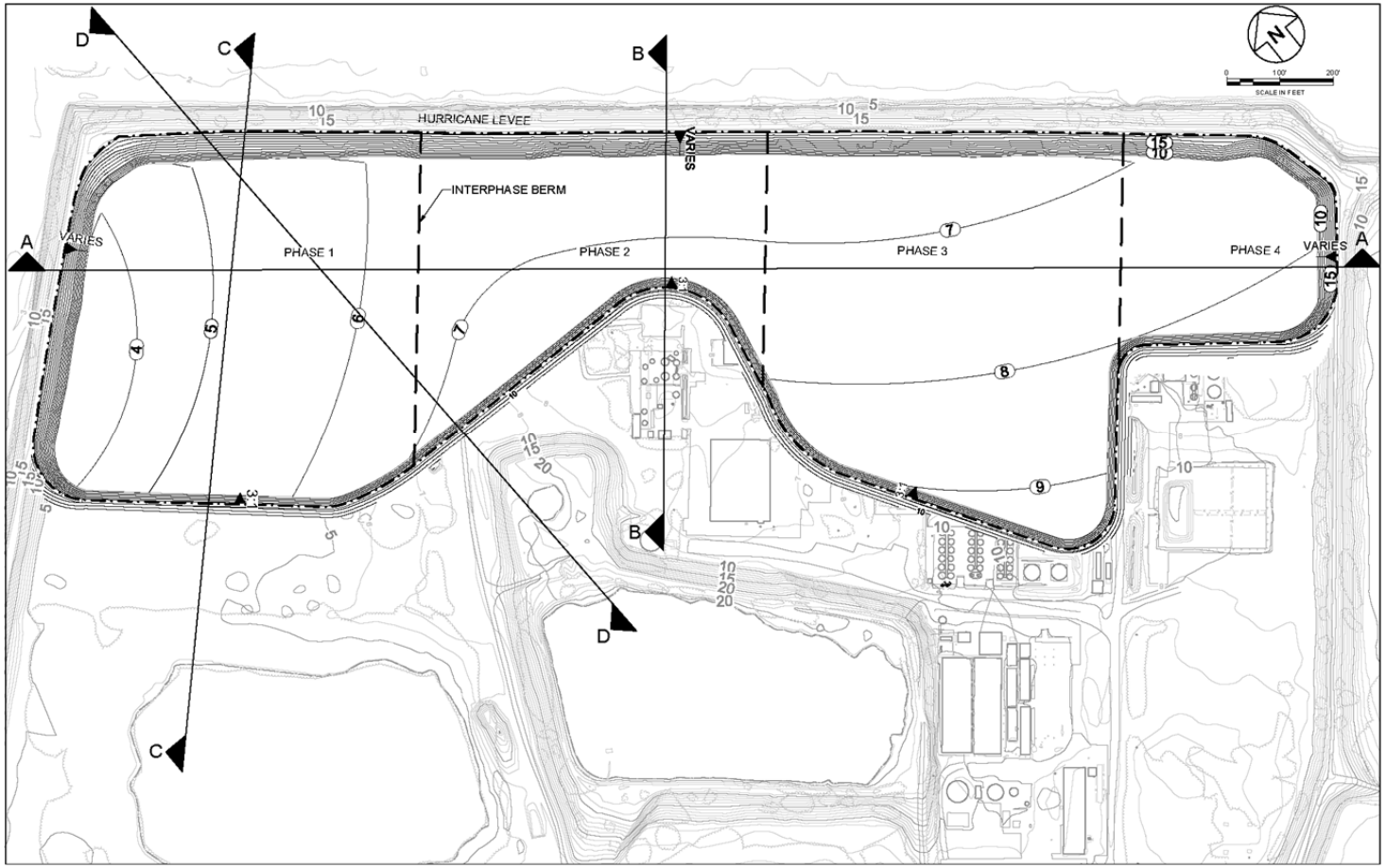


Figure 2: Top of Soil Subgrade Grading Plan.
The critical cross sections analyzed for slope stability are shown on the top of soil subgrade plan.

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

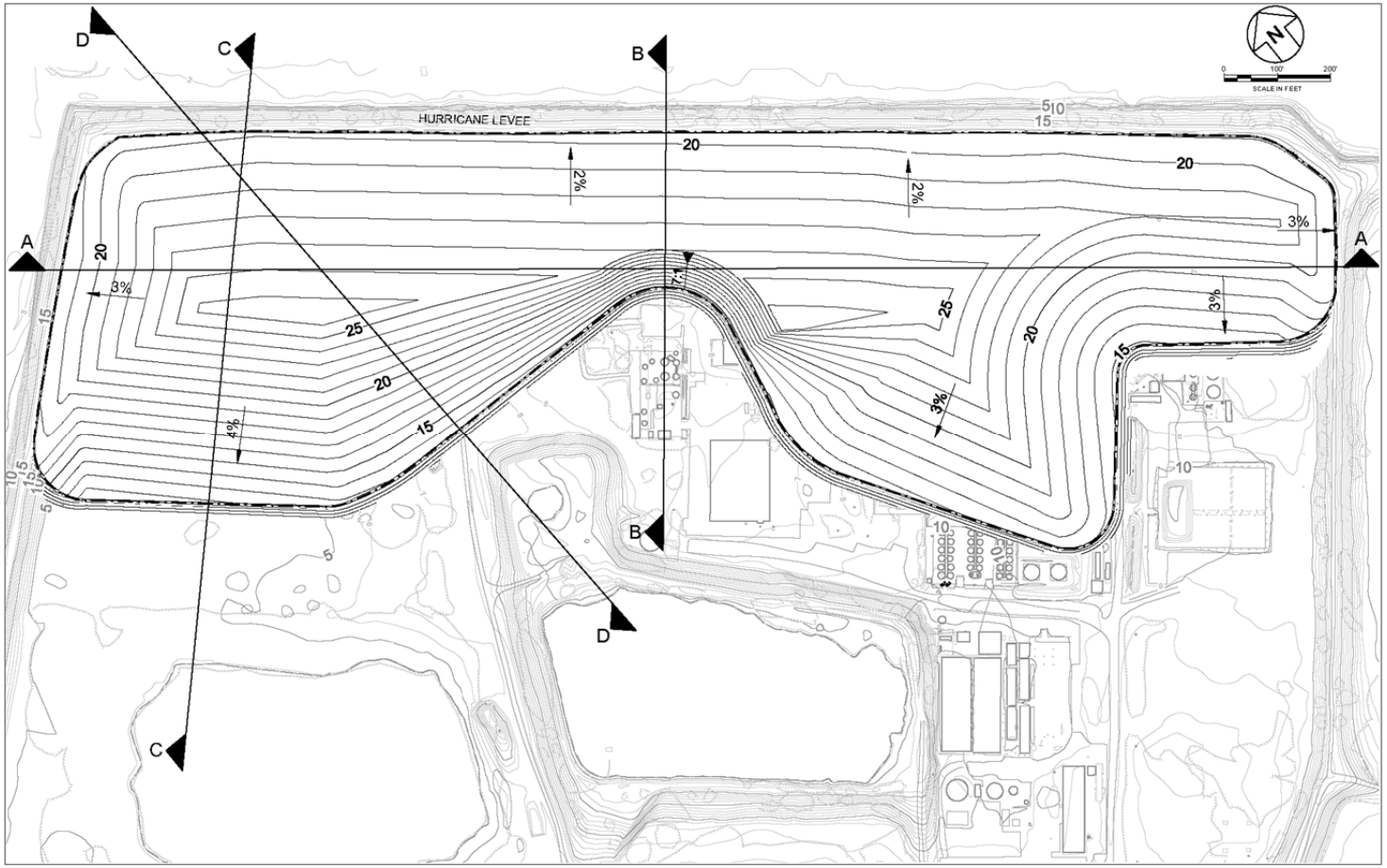


Figure 3: Top of Final Cover Grading Plan.
The critical cross sections analyzed for slope stability are shown on the top of final cover plan.

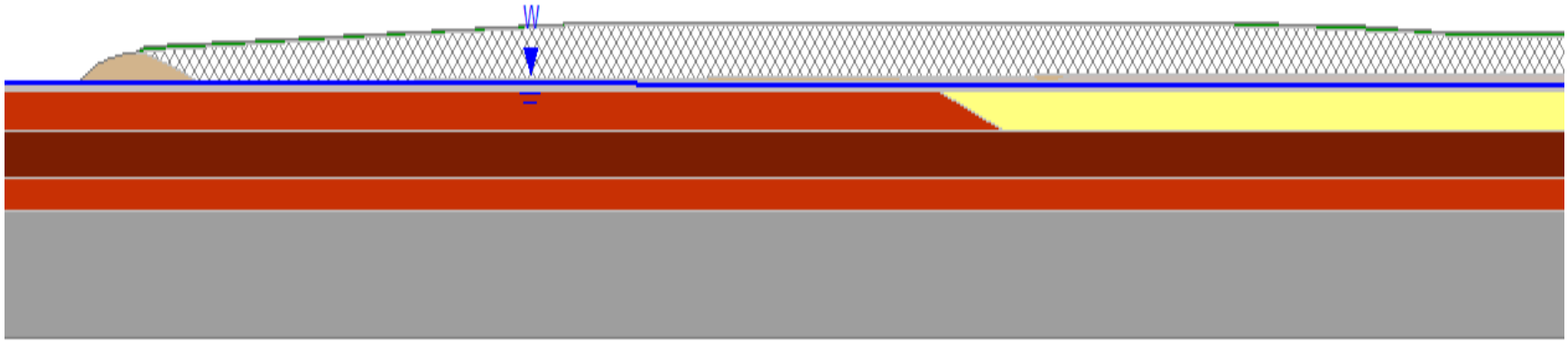
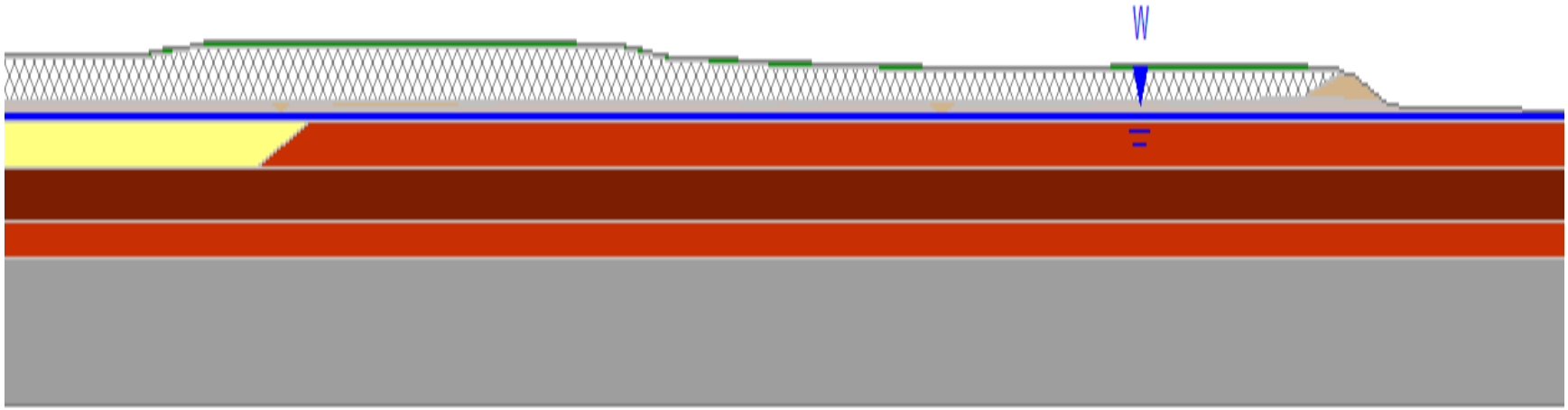


Figure 4: Section A-A' – (Top – North Half / Bottom – South Half) (Location indicated on Figures 2 and 3).



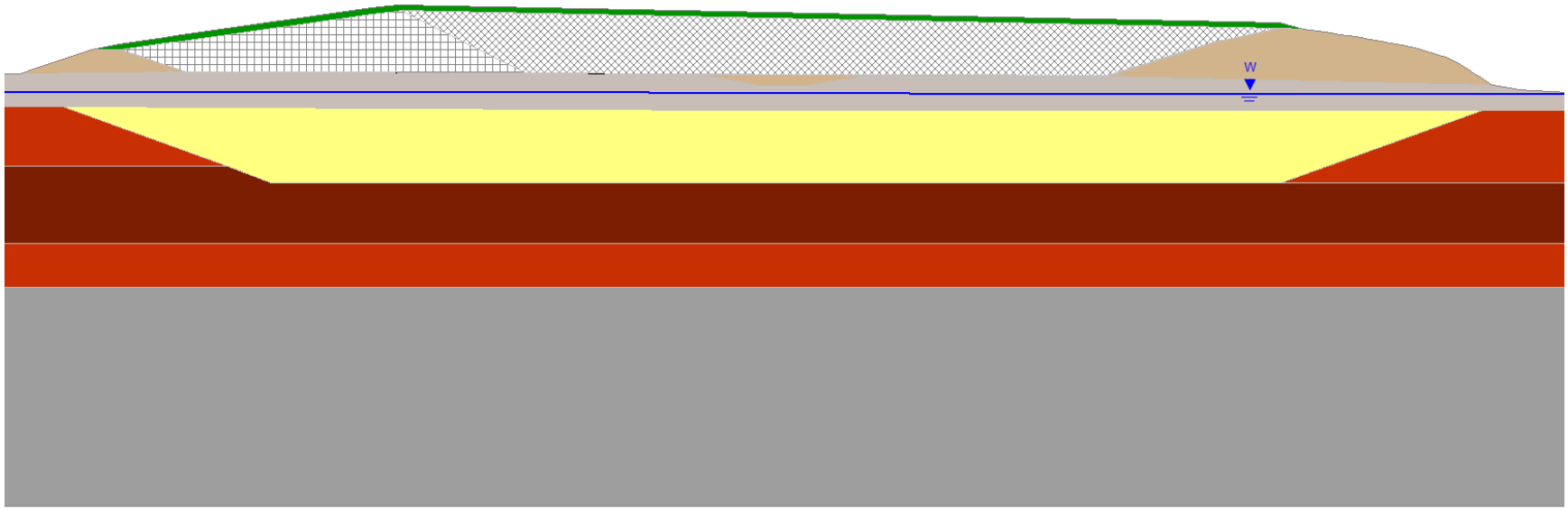


Figure 5: Section B-B' (Location indicated on Figures 2 and 3).

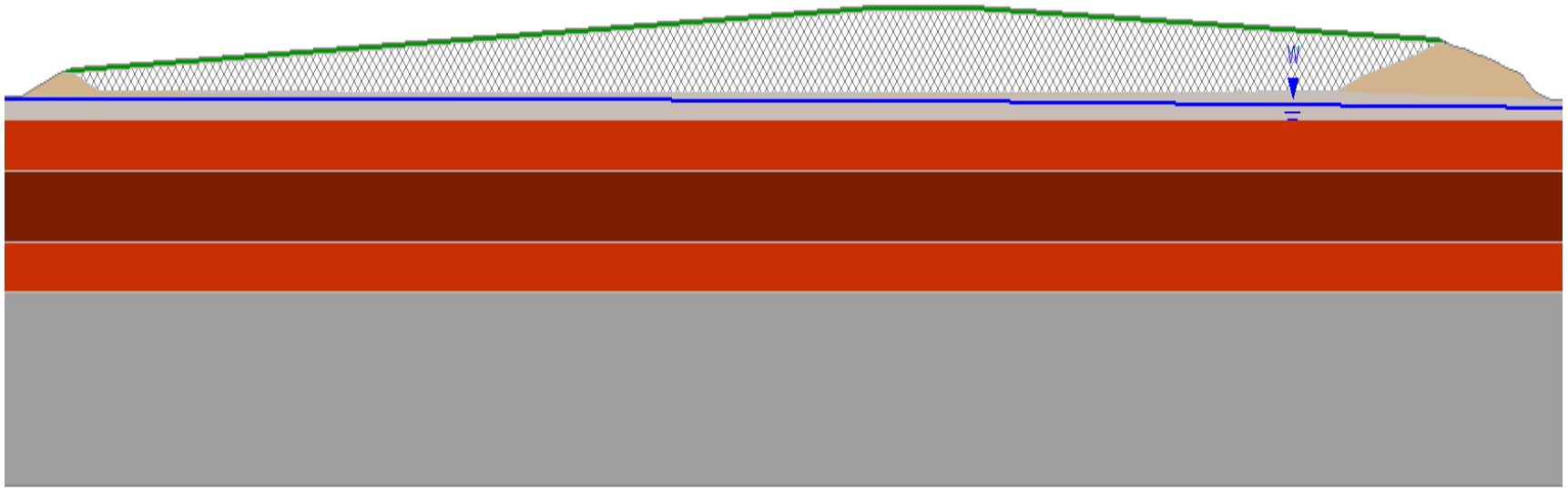


Figure 6: Section C-C' (Location indicated on Figures 2 and 3).

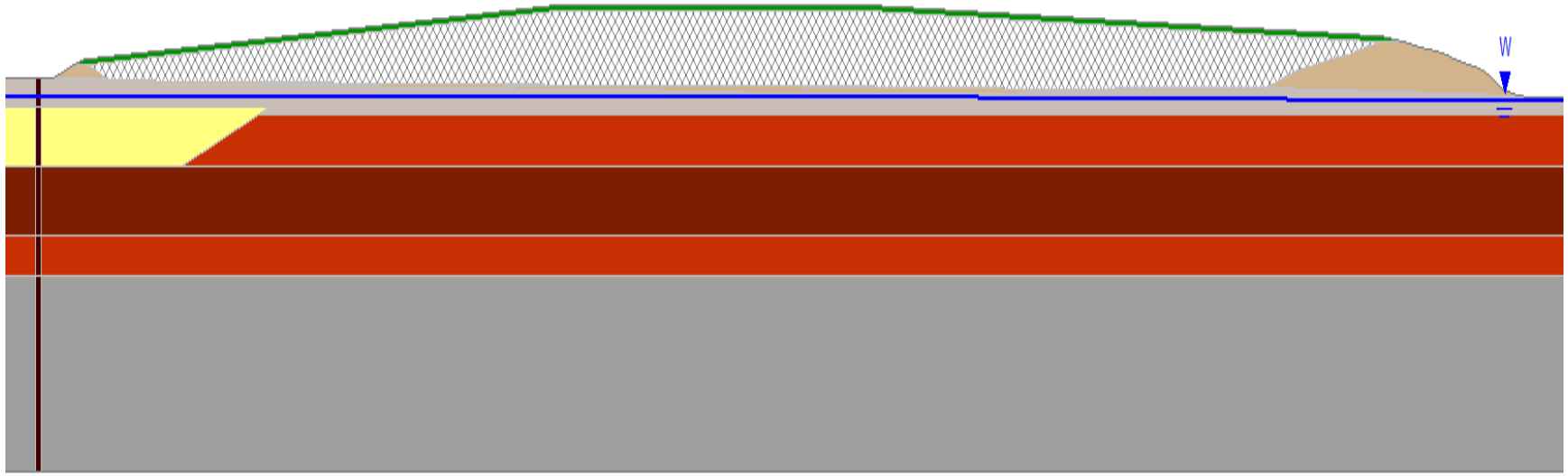


Figure 7: Section D-D' (Location indicated on Figures 2 and 3).

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

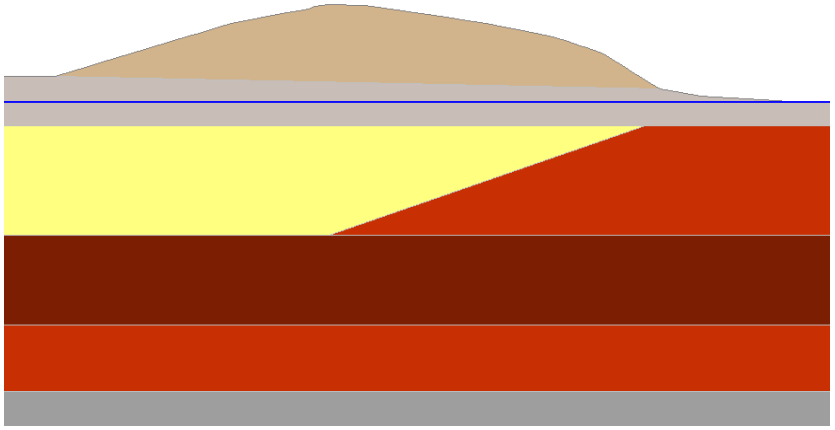
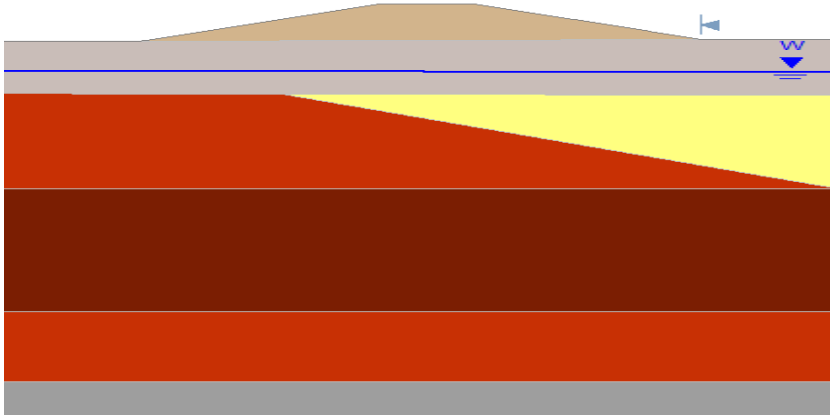


Figure 8: Levee Slope (top) and Berm Slope (bottom).
These sections are modeled from Section B (Figure 5) to analyze only the levee and berm slopes.



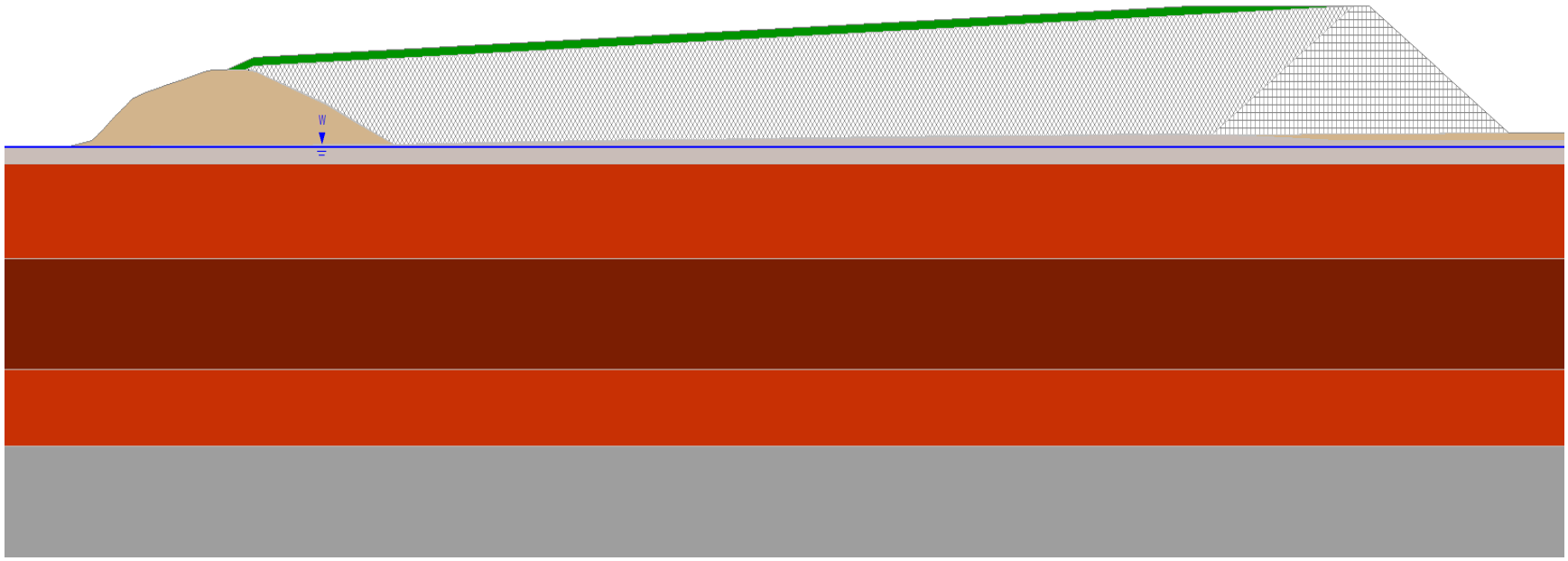


Figure 9: Interim Landfill Slope
This section is modeled from Section A to analyze the interim landfill condition when the peak waste height is reached.

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

APPENDIX 1

Drawings from Previously Prepared Reports

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Appendix 1.1
Drawings from Preliminary Site Characterization Report (2004)

LEGEND

- PROPERTY BOUNDARY
- D D' - CROSS-SECTION LOCATION
- APPROXIMATE BOUNDARY OF PALEOSTREAM CHANNEL

SOURCE: TNRIS DOQQ No. 2994412
VIRGINIA POINT NE, TEXAS

0 800 1600
APPROXIMATE SCALE IN FEET

MALONE SERVICE CO.
SUPERFUND SITE

URS
9801 Westheimer
Suite 500
Houston, Texas 77042
PH: (713) 914-6699
FAX: (713) 914-8404

SCALE:	DRAWN BY: SJF	DATE: 2-10-04
AS SHOWN	CHKD. BY:	DATE:

CROSS-SECTION
LOCATION MAP

FILE NO.
CROSS-SECT-LOCS

FIGURE NO.
5

FILE NAME:MALONE-CROSS-SECT-LOCS.dwg
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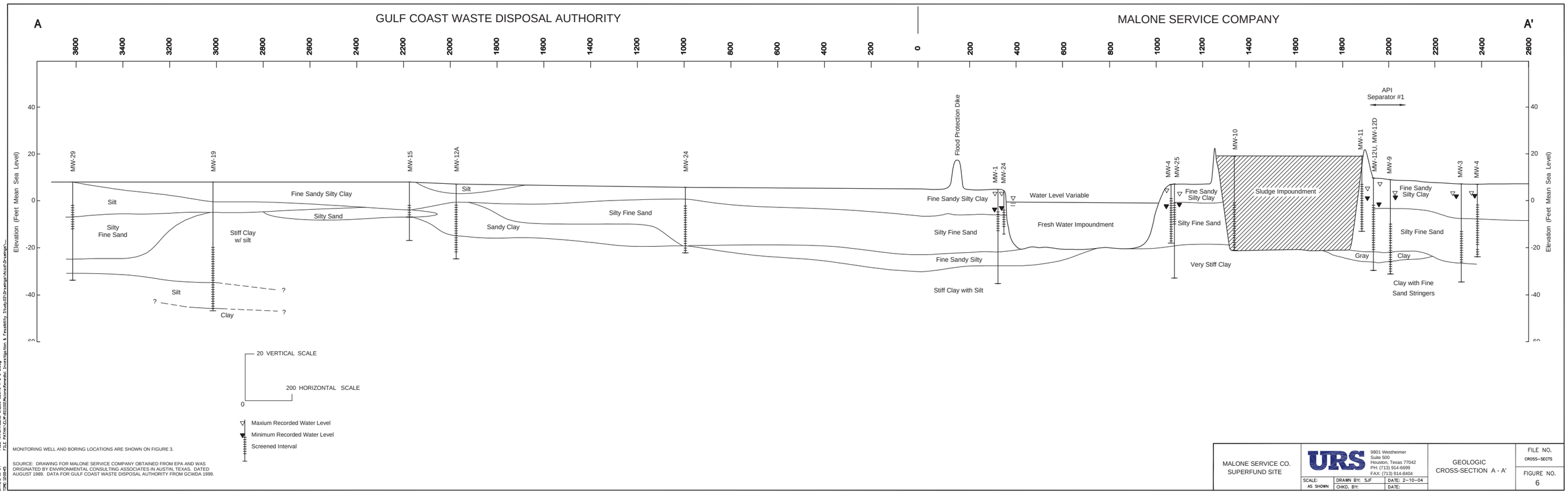
TIME:12:00:45



MONITORING WELL AND BORING LOCATIONS ARE SHOWN ON FIGURE 3.

SOURCE: DRAWING FOR MALONE SERVICE COMPANY OBTAINED FROM EPA AND WAS ORIGINATED BY ENVIRONMENTAL CONSULTING ASSOCIATES IN AUSTIN, TEXAS. DATED AUGUST 1989. DATA FOR GULF COAST WASTE DISPOSAL AUTHORITY FROM GCWDA 1999.

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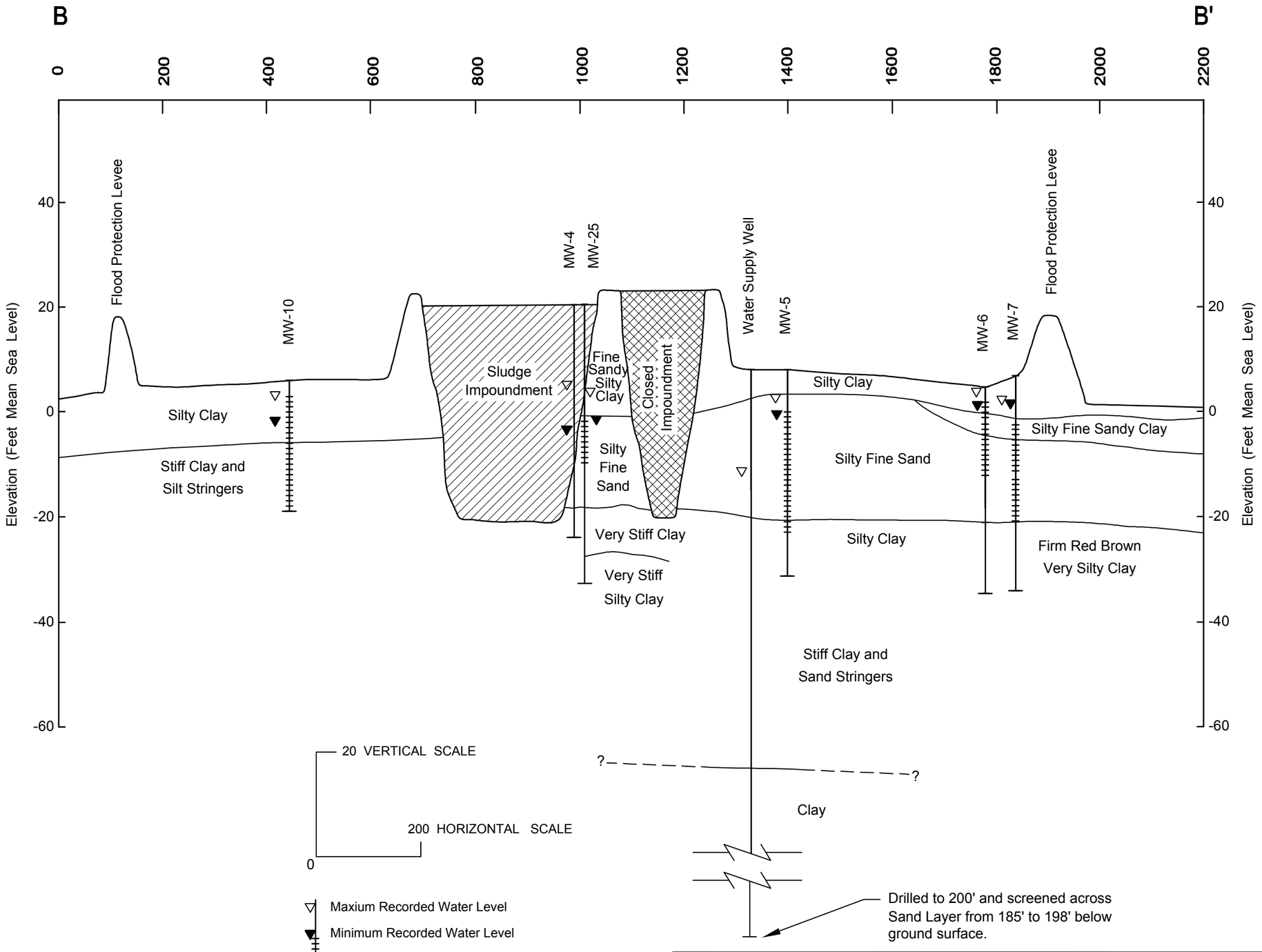
TIME: 12:04:43
FILE: W:\MALONE-JOCOS_SECTS-A-A'-C-C'.dwg
FILE PATH: \CLIENT\HOUSTON\Projects\Malone Service Company Superfund Site\Operable Unit 2 Investigation & Feasibility Study\07-Drawings\Acad\Drawings\

MALONE SERVICE CO. SUPERFUND SITE	URS 9801 Westheimer Suite 500 Houston, Texas 77042 PH: (713) 914-6699 FAX: (713) 914-8404	GEOLOGIC CROSS-SECTION A - A'	FILE NO. CROSS-SECTS
	SCALE: AS SHOWN / DRAWN BY: SJF / DATE: 2-10-04 / CHKD. BY: / DATE:		FIGURE NO. 6



MONITORING WELL AND BORING LOCATIONS ARE SHOWN ON FIGURE 3.

SOURCE: DRAWING FOR MALONE SERVICE COMPANY OBTAINED FROM EPA AND WAS ORIGINATED BY ENVIRONMENTAL CONSULTING ASSOCIATES IN AUSTIN, TEXAS. DATED AUGUST 1989.

MALONE SERVICE CO.
SUPERFUND SITE

URS
9801 Westheimer
Suite 500
Houston, Texas 77042
PH: (713) 914-6699
FAX: (713) 914-8404

SCALE:	DRAWN BY: SJF	DATE: 2–10–04
AS SHOWN	CHKD. BY:	DATE:

GEOLOGIC
CROSS-SECTION B - B'

FILE NO.
CROSS–SECTS

FIGURE NO.
7

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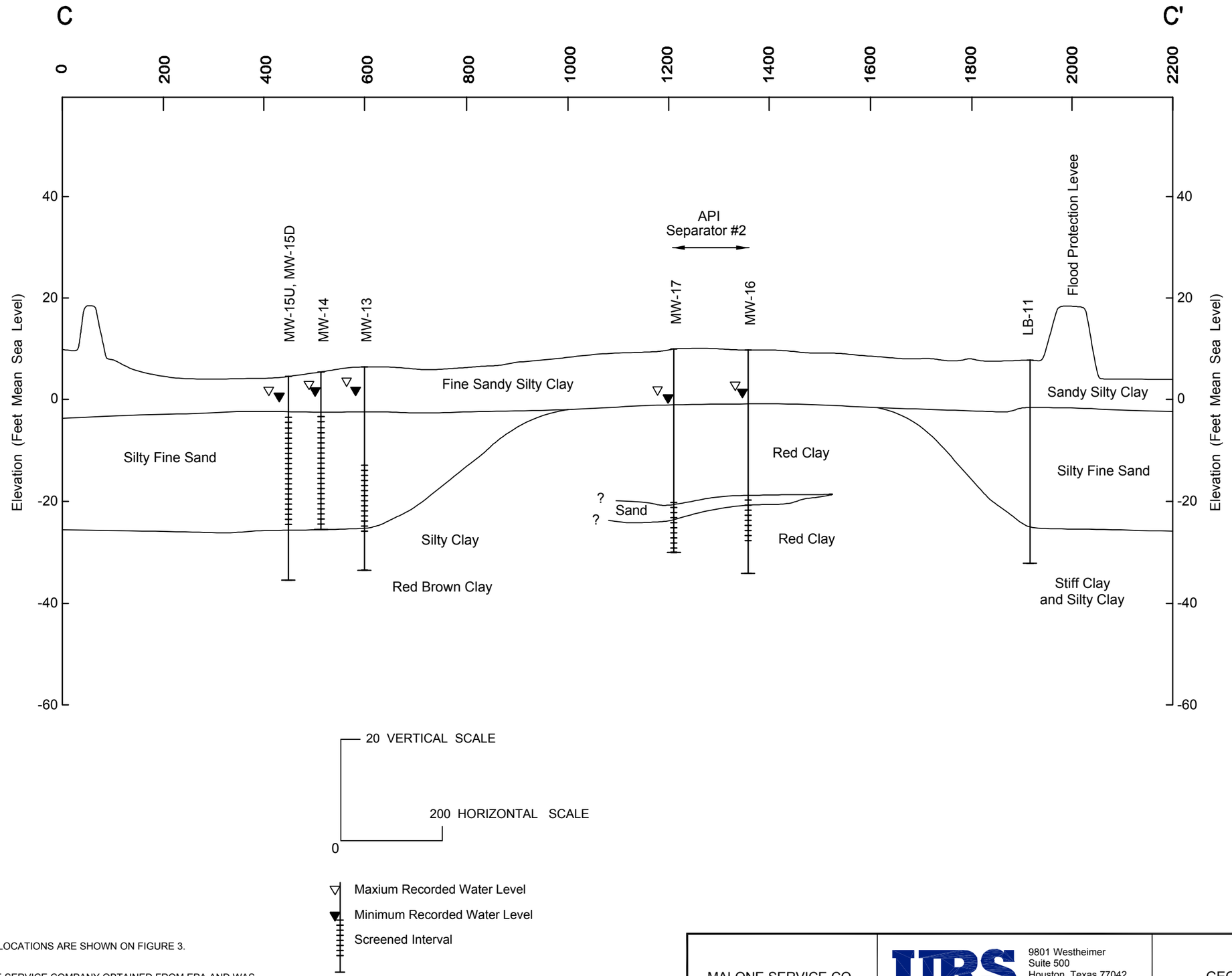

MONITORING WELL AND BORING LOCATIONS ARE SHOWN ON FIGURE 3.

SOURCE: DRAWING FOR MALONE SERVICE COMPANY OBTAINED FROM EPA AND WAS ORIGINATED BY ENVIRONMENTAL CONSULTING ASSOCIATES IN AUSTIN, TEXAS. DATED AUGUST 1989.

MALONE SERVICE CO.
SUPERFUND SITE

URS
9801 Westheimer
Suite 500
Houston, Texas 77042
PH: (713) 914-6699
FAX: (713) 914-8404

SCALE:	DRAWN BY: SJF	DATE: 2-10-04
AS SHOWN	CHKD. BY:	DATE:

GEOLOGIC
CROSS-SECTION C - C'

FILE NO.
CROSS-SECTS

FIGURE NO.
8

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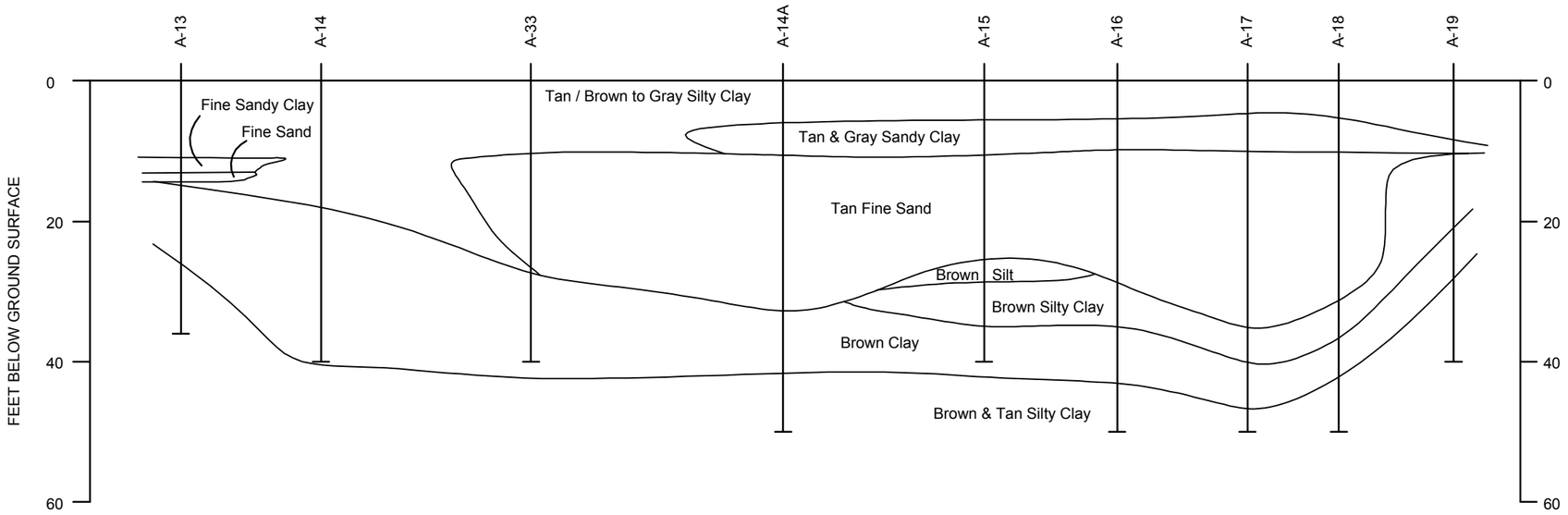
D

D'



20 VERTICAL SCALE

200 HORIZONTAL SCALE

MONITORING WELL AND BORING LOCATIONS ARE SHOWN ON FIGURE 3.

SOURCE: LAW ENGINEERING, 1982, GROUNDWATER ASSESSMENT AND CLOSURE PLAN.

MALONE SERVICE CO.
SUPERFUND SITE

URS
9801 Westheimer
Suite 500
Houston, Texas 77042
PH: (713) 914-6699
FAX: (713) 914-8404

SCALE:	DRAWN BY: SJF	DATE: 2-10-04
AS SHOWN	CHKD. BY:	DATE:

GEOLOGIC
CROSS-SECTION D - D'

FILE NO.
CROSS-SECTS

FIGURE NO.
9

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TIME=12:00:45

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Appendix 1.2
Drawings from Remedial Investigation Report (2006)

K:\ELM\611102_Malone_Remedial Investigation & Feasibility Study_03\Drawings\Acad\Drawings\RI-FS PLAN\Fig 2 - Site Features Map.dwg Layout: Feb 01, 2006 - 9:47am

SOURCE:

AERIAL PHOTO FROM 2003-2004 H-GAC AND GDC DIGITAL ORTHOPHOTO COVERAGE AREA.
NAD 83, TEXAS STATE PLANE, SOUTH CENTRAL ZONE COORDINATE SYSTEM.

0 300 600
APPROXIMATE SCALE IN FEET

MALONE SERVICE CO.
SUPERFUND SITE

URS
9801 Westheimer
Suite 500
Houston, Texas 77042
PH: (713) 914-6699
FAX: (713) 914-8404

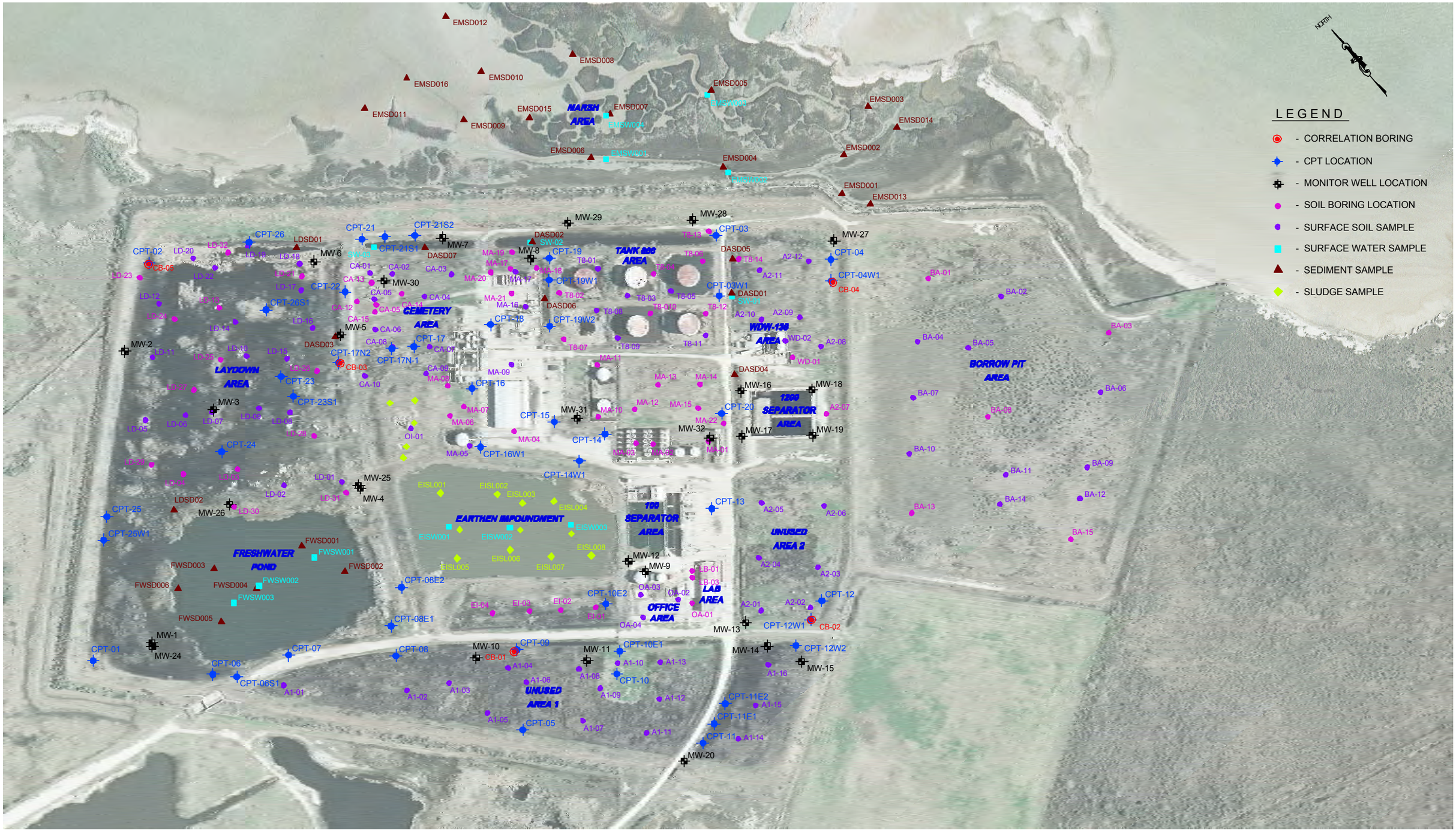
SCALE:	DRAWN BY: SJF	DATE: 1-31-06
AS SHOWN	CHKD BY: BB	DATE: 1-31-06

SITE FEATURES MAP

FILE No.
Site Features Map.dwg

FIGURE No.
2

K:\ELM\811102_Malone_Remedial Investigation & Feasibility Study_03\Drawings\Acad\Drawings\RI-FS PLAN\Fig 3 - Sample Locations.dwg Layout1 Feb 02, 2006 - 10:28am



SOURCE:

AERIAL PHOTO FROM 2003-2004 H-GAC AND GDC DIGITAL ORTHOPHOTO COVERAGE AREA.
NAD 83, TEXAS STATE PLANE, SOUTH CENTRAL ZONE COORDINATE SYSTEM.

CPTS, MONITOR WELLS, AND SOIL SAMPLE LOCATIONS WERE SURVEYED BY THE WILSON SURVEY GROUP, INC.

SEDIMENT AND SURFACE WATER SAMPLES LOCATIONS WERE SURVEYED BY BENCHMARK ECOLOGICAL SERVICES, INC., AND BY THE WILSON SURVEY GROUP, INC.

0 300 600

APPROXIMATE SCALE IN FEET

MALONE SERVICE CO.
SUPERFUND SITE

URS
9801 Westheimer
Suite 500
Houston, Texas 77042
PH: (713) 914-6699
FAX: (713) 914-8404

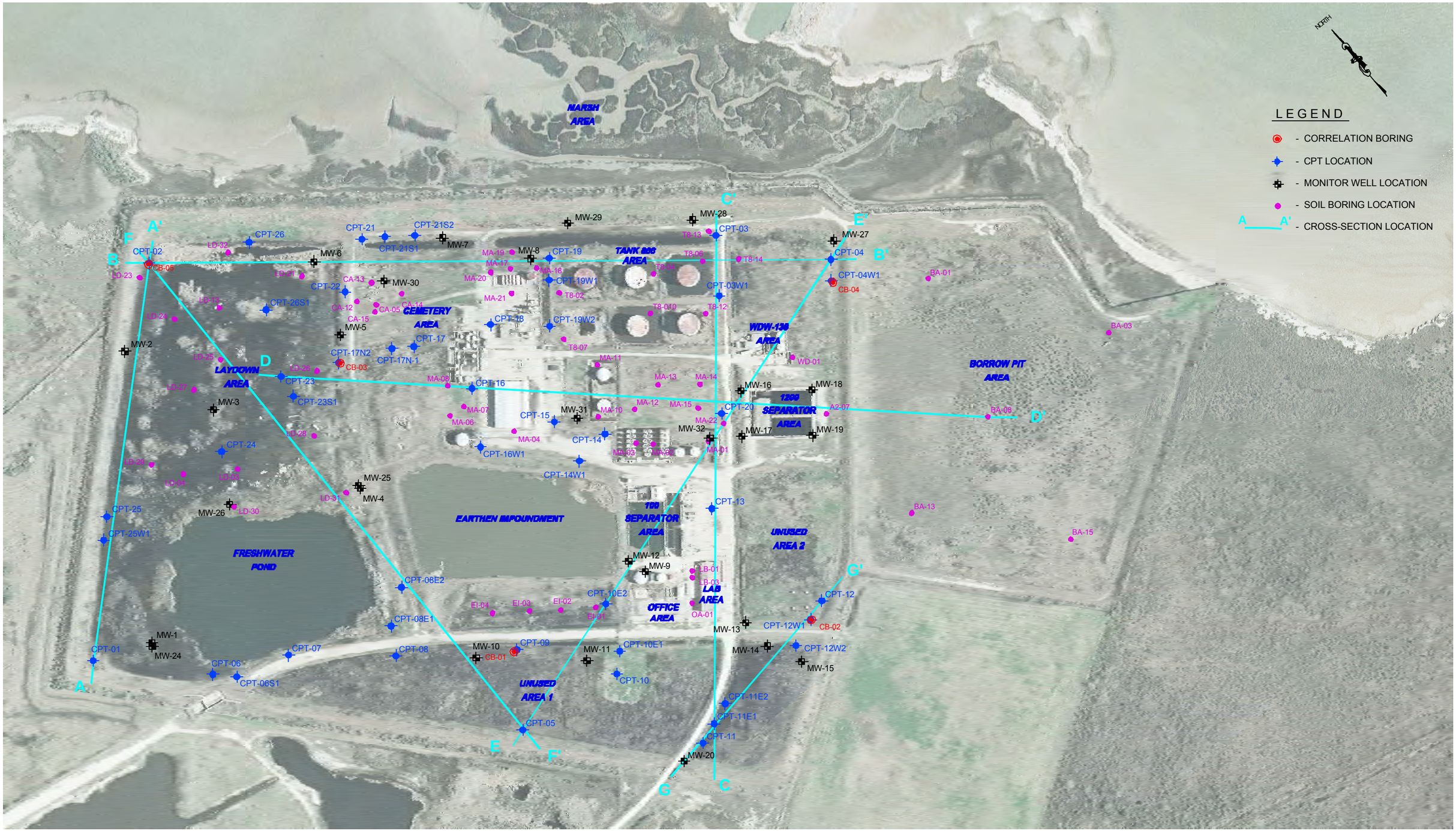
SCALE:	DRAWN BY: SJF	DATE: 2-1-06
AS SHOWN	CHKD BY: BB	DATE: 2-1-06

SITE LAYOUT AND SAMPLE LOCATIONS

FILE No.
Sample Locations.dwg

FIGURE No.
3

K:\ELM\911102_Malone_Remedial Investigation & Feasibility Study_03\Drawings\Acad\Drawings\RI-FS PLAN\Fig 10 - Cross-Section Locations.dwg\Layout1 Feb 02, 2006 - 9:50am



SOURCE:

AERIAL PHOTO FROM 2003-2004 H-GAC AND GDC DIGITAL ORTHOPHOTO COVERAGE AREA.
NAD 83, TEXAS STATE PLANE, SOUTH CENTRAL ZONE COORDINATE SYSTEM.

SAMPLE LOCATIONS WERE SURVEYED BY THE WILSON SURVEY GROUP, INC.

0 300 600
APPROXIMATE SCALE IN FEET

MALONE SERVICE CO.
SUPERFUND SITE

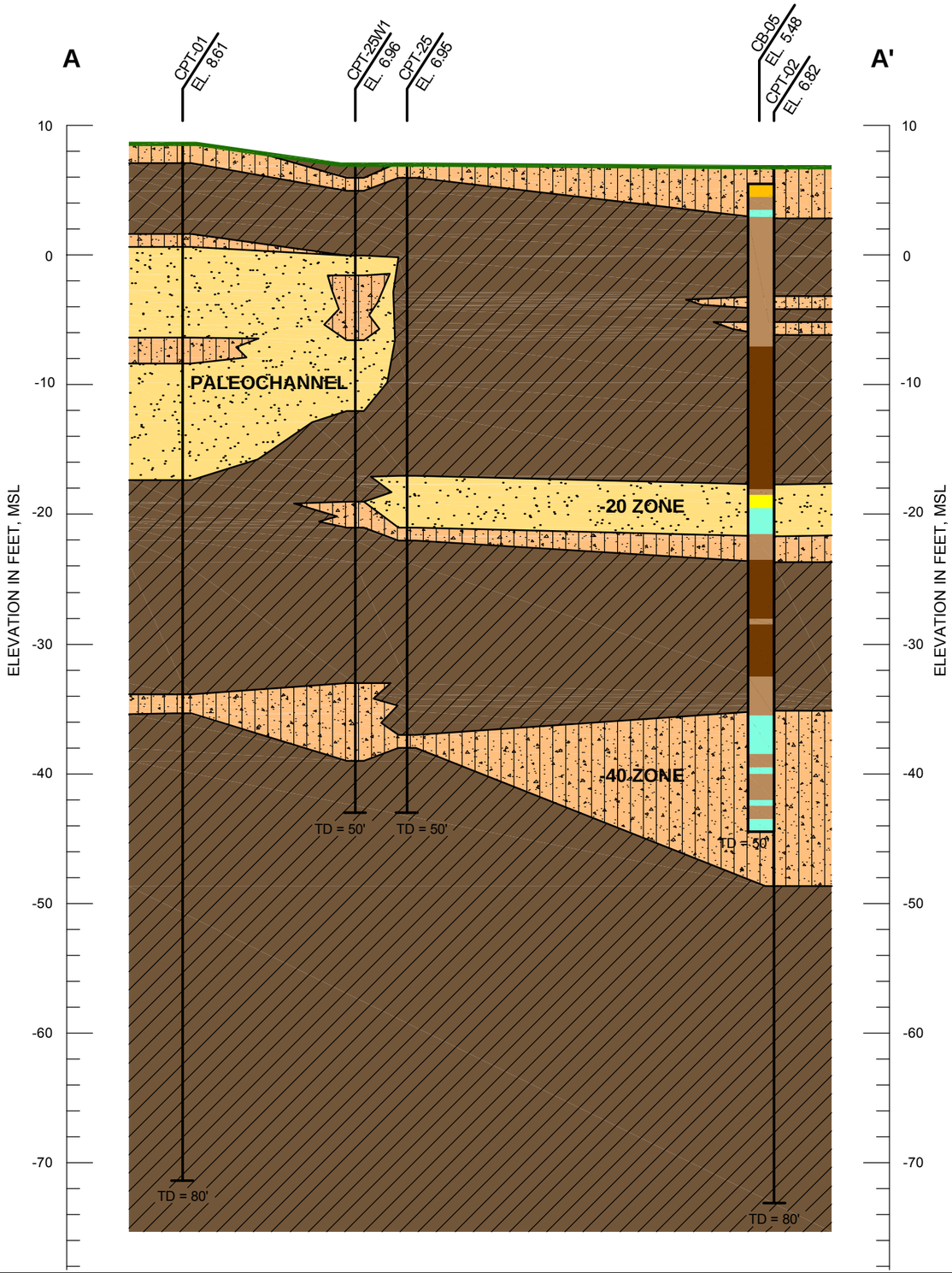
URS
9801 Westheimer
Suite 500
Houston, Texas 77042
PH: (713) 914-6699
FAX: (713) 914-8404

SCALE:	DRAWN BY: SJF	DATE: 2-1-06
AS SHOWN	CHKD BY: BB	DATE: 2-1-06

CROSS-SECTION LOCATIONS

FILE No.
Cross-Section Locations.dwg

FIGURE No.
10



LEGEND:

CPT-02
EL. 6.82

DESIGNATION NUMBER WITH GROUND SURFACE ELEVATION, FEET

CPT - CONE PENETROMETER TEST SOIL BORING

CB - CORRELATION SOIL BORING

MW - MONITORING WELL

TD = 25'

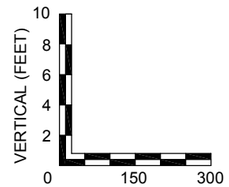
TOTAL DEPTH IN FEET (BELOW GROUND SURFACE)

MONITORING WELL / CORRELATION BORING LITHOLOGY - DEC 2005

- CLAY (CH)
- SILTY CLAY / SANDY CLAY (CL)
- SILT / CLAYEY SILT (ML)
- CLAYEY SAND (SC)
- SILTY SAND (SM)

PREVIOUS INTERPRETED LITHOLOGY

- CLAY (CH / CL)
- CLAY / SAND / SILT MIXTURES AND/OR INTERBEDDED (CL / SC / SM / ML)
- SAND (SP / SW)



VERTICAL EXAGGERATION = 30 x

Note:

1. Ground surface elevations were surveyed by Wilson Surveying Group, Inc.

URS
9801 WESTHEIMER, SUITE 500
HOUSTON, TEXAS 77042
PH: (713) 914-6699
FAX: (713) 789-8404

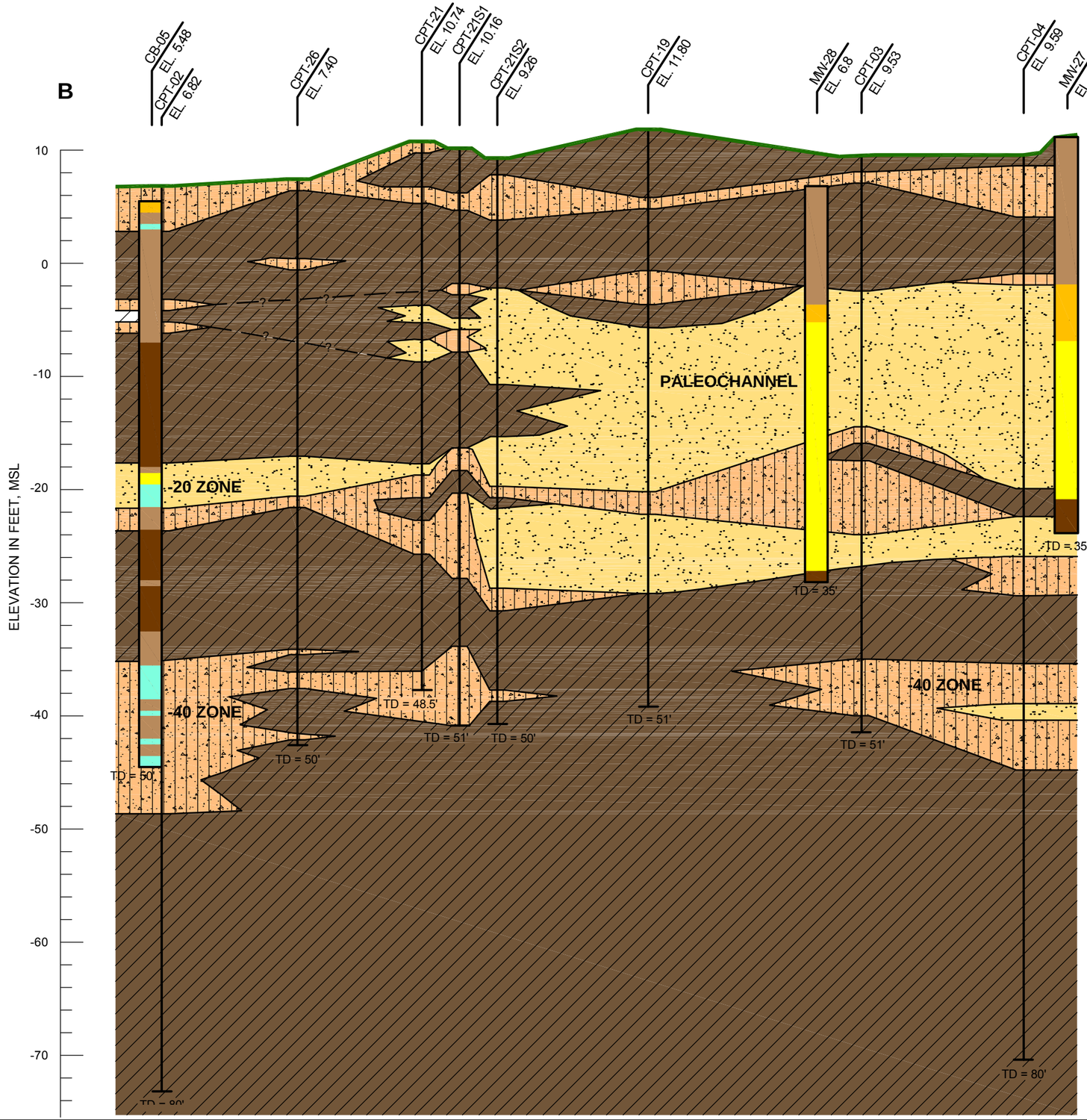
Title: **CROSS-SECTION A - A'**

Project: Malone Service Co. Superfund Site

Client: **Malone Cooperating Parties**

Scale:	Drawn by:	Date:	Project No.:	File Name:	Figure:
As Shown	SJF	2-1-06	25008093	Cross-Sects A-B-C-D-E-F-G.dwg	11
	Chk'd by: JK	Date: 2-1-06			

K:\ELW\311102_Malone_Remedial Investigation & Feasibility Study_03\Drawings\Acad\Drawings\RI-FS PLAN\Fig 11 thru 17 - Cross-Sects A-B-C-D-E-F-G.dwg-A' Feb 03, 2006 - 10:09am



LEGEND:

CPT-02 EL 6.82 — DESIGNATION NUMBER WITH GROUND SURFACE ELEVATION, FEET

CPT - CONE PENETROMETER TEST SOIL BORING

CB - CORRELATION SOIL BORING

MW - MONITORING WELL

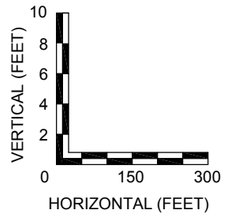
TD = 50' — TOTAL DEPTH IN FEET (BELOW GROUND SURFACE)

MONITORING WELL / CORRELATION BORING LITHOLOGY - DEC 2005

- CLAY (CH)
- SILTY CLAY / SANDY CLAY (CL)
- SILT / CLAYEY SILT (ML)
- CLAYEY SAND (SC)
- SILTY SAND (SM)

PREVIOUS INTERPRETED LITHOLOGY

- CLAY (CH / CL)
- CLAY / SAND / SILT MIXTURES AND/OR INTERBEDDED (CL / SC / SM / ML)
- SAND (SP / SW)



VERTICAL EXAGGERATION = 30 x

Note:

1. Ground surface elevations were surveyed by Wilson Surveying Group, Inc.

URS
9801 WESTHEIMER, SUITE 500
HOUSTON, TEXAS 77042
PH: (713) 914-6699
FAX: (713) 789-8404

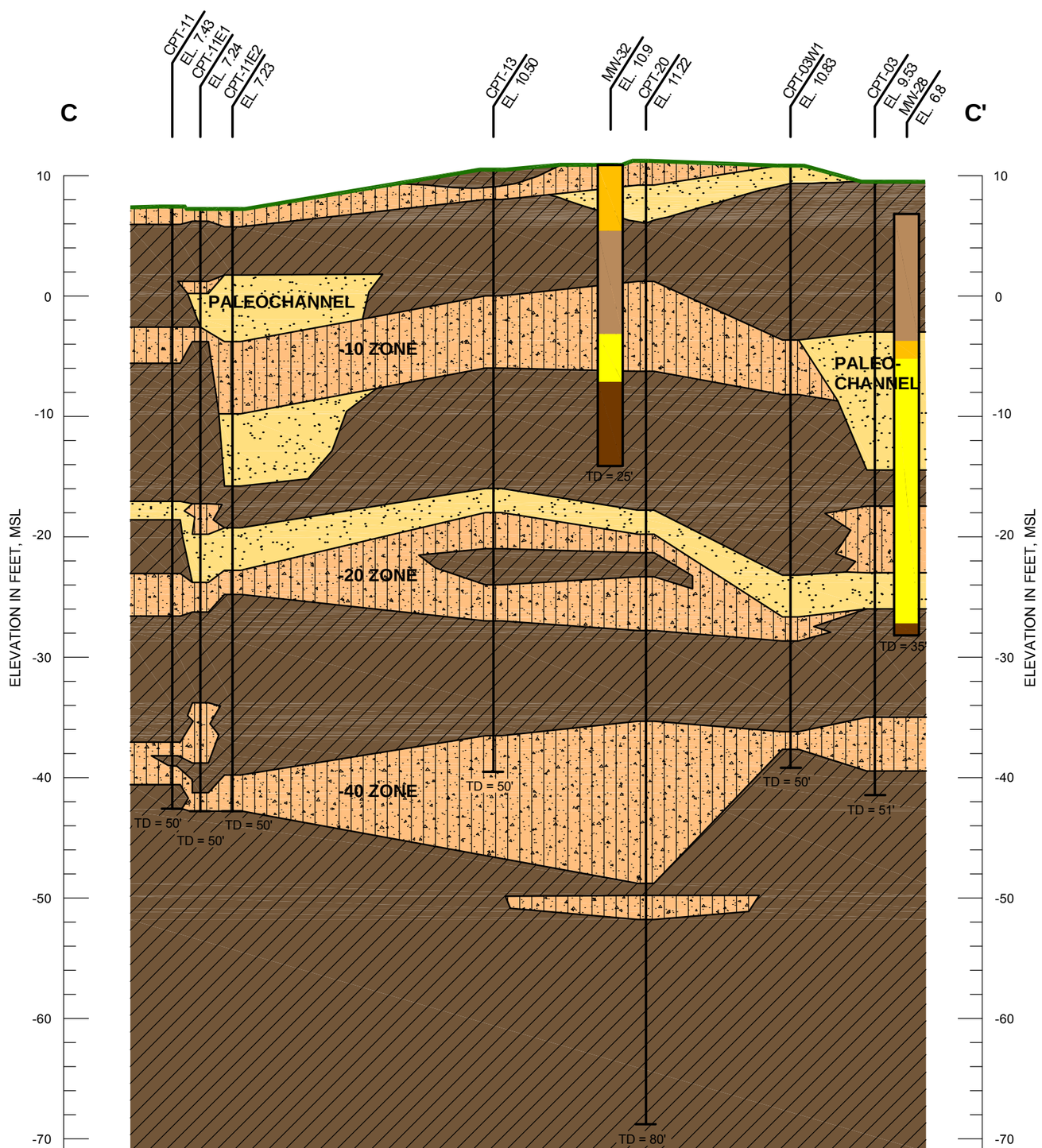
Title: **CROSS-SECTION B - B'**

Project: Malone Service Co. Superfund Site

Client: **Malone Cooperating Parties**

Scale:	Drawn by:	Date:	Project No.:	File Name:	Figure:
As Shown	SJF	2-1-06	25008093	Cross-Sects A-B-C-D-E-F-G.dwg	12
	Chk'd by: JK	Date: 2-1-06			

K:\ELM\811102_Malone_Remedial Investigation & Feasibility Study_03\Drawings\Acad\Drawings\RI-FS PLAN\Fig 11 thru 17 - Cross-Sects A-B-C-D-E-F-G.dwgB-B' Feb 03, 2006 - 10:10am



LEGEND:

CPT-02
EL 6.82

DESIGNATION NUMBER WITH GROUND SURFACE ELEVATION, FEET

CPT - CONE PENETROMETER TEST SOIL BORING

CB - CORRELATION SOIL BORING

MW - MONITORING WELL

TD = 25'

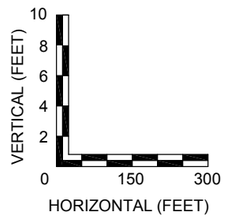
TOTAL DEPTH IN FEET (BELOW GROUND SURFACE)

MONITORING WELL / CORRELATION BORING LITHOLOGY - DEC 2005

- CLAY (CH)
- SILTY CLAY / SANDY CLAY (CL)
- SILT / CLAYEY SILT (ML)
- CLAYEY SAND (SC)
- SILTY SAND (SM)

PREVIOUS INTERPRETED LITHOLOGY

- CLAY (CH / CL)
- CLAY / SAND / SILT MIXTURES AND/OR INTERBEDDED (CL / SC / SM / ML)
- SAND (SP / SW)



VERTICAL EXAGGERATION = 30 x

Note:

1. Ground surface elevations were surveyed by Wilson Surveying Group, Inc.

URS
9801 WESTHEIMER, SUITE 500
HOUSTON, TEXAS 77042
PH: (713) 914-6699
FAX: (713) 789-8404

Title: **CROSS-SECTION C - C'**

Project: Malone Service Co. Superfund Site

Client: **Malone Cooperating Parties**

Scale:	Drawn by:	Date:	Project No.:	File Name:	Figure:
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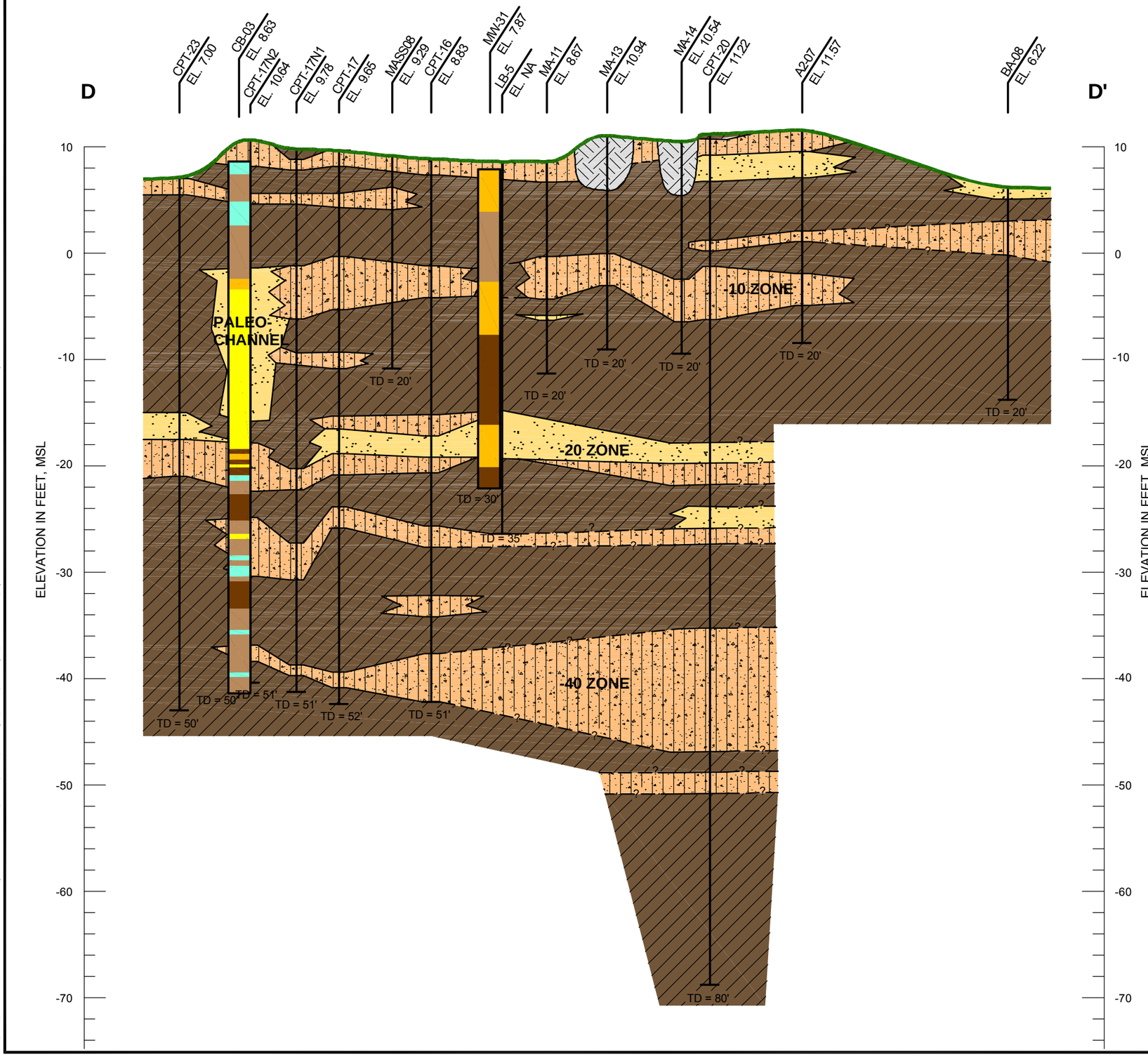
	Chk'd by: JK	Date: 2-1-06			

K:\ELM\311102_Malone_Remedial Investigation & Feasibility Study_03\Drawings\Acad\Drawings\RI-FS PLAN\Fig 11 thru 17 - Cross-Sects A-B-C-D-E-F-G.dwgC-C' Feb 03, 2006 - 10:11am



LEGEND:

CPT-02 EL. 6.82

TD = 25'

DESIGNATION NUMBER WITH GROUND SURFACE ELEVATION, FEET

CPT - CONE PENETROMETER TEST SOIL BORING

CB - CORRELATION SOIL BORING

MW - MONITORING WELL

TOTAL DEPTH IN FEET (BELOW GROUND SURFACE)

MONITORING WELL / CORRELATION BORING LITHOLOGY - DEC 2005

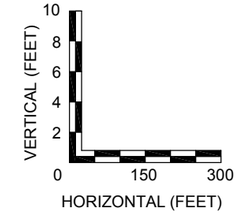
- CLAY (CH)
- SILTY CLAY / SANDY CLAY (CL)
- SILT / CLAYEY SILT (ML)
- CLAYEY SAND (SC)
- SILTY SAND (SM)

PREVIOUS INTERPRETED LITHOLOGY

- CLAY (CH / CL)
- CLAY / SAND / SILT MIXTURES AND/OR INTERBEDDED (CL / SC / SM / ML)
- SAND (SP / SW)
- SLUDGE MATERIAL

LB-5 SOIL BORING WAS INSTALLED BY LAW ENGINEERING (LAW 1982) AND THE GROUND SURFACE ELEVATION IS NOT AVAILABLE (NA).

MA, A2, AND BA ARE SUBSURFACE SOIL BORINGS.



VERTICAL EXAGGERATION = 30 x

Note:

1. Ground surface elevations were surveyed by Wilson Surveying Group, Inc.

URS
9801 WESTHEIMER, SUITE 500
HOUSTON, TEXAS 77042
PH: (713) 914-6699
FAX: (713) 789-8404

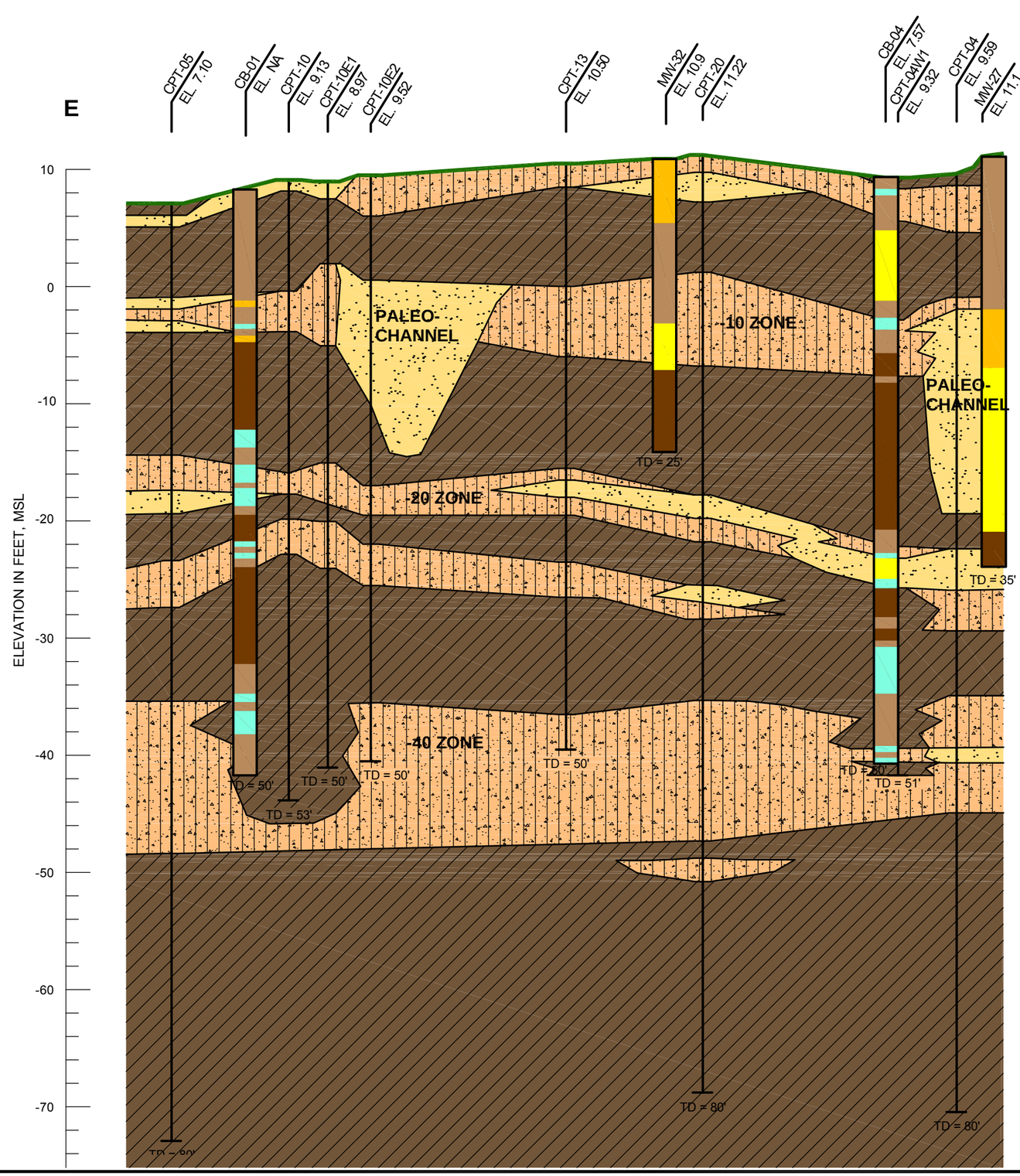
Title: **CROSS-SECTION D - D'**

Project: Malone Service Co. Superfund Site

Client: **Malone Cooperating Parties**

Scale:	Drawn by:	Date:	Project No.:	File Name:	Figure:
As Shown	SJF	2-1-06	25008093	Cross-Sects A-B-C-D-E-F-G.dwg	14
	Chk'd by: JK	Date: 2-1-06			

K:\ELW\B111102_Malone_Remedial Investigation & Feasibility Study_03\Drawings\Acad\Drawings\RI-FS PLAN\Fig 11 thru 17 - Cross-Sects A-B-C-D-E-F-G.dwgD-D' Feb 03, 2006 - 10:12am



LEGEND:

CPT-02 EL 6.82

DESIGNATION NUMBER WITH GROUND SURFACE ELEVATION, FEET

CPT - CONE PENETROMETER TEST SOIL BORING

CB - CORRELATION SOIL BORING

MW - MONITORING WELL

TD = 25'

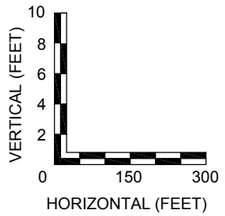
TOTAL DEPTH IN FEET (BELOW GROUND SURFACE)

MONITORING WELL / CORRELATION BORING LITHOLOGY - DEC 2005

- CLAY (CH)
- SILTY CLAY / SANDY CLAY (CL)
- SILT / CLAYEY SILT (ML)
- CLAYEY SAND (SC)
- SILTY SAND (SM)

PREVIOUS INTERPRETED LITHOLOGY

- CLAY (CH / CL)
- CLAY / SAND / SILT MIXTURES AND/OR INTERBEDDED (CL / SC / SM / ML)
- SAND (SP / SW)



VERTICAL EXAGGERATION = 30 x

Note:

1. Ground surface elevations were surveyed by Wilson Surveying Group, Inc.

URS
9801 WESTHEIMER, SUITE 500
HOUSTON, TEXAS 77042
PH: (713) 914-6699
FAX: (713) 789-8404

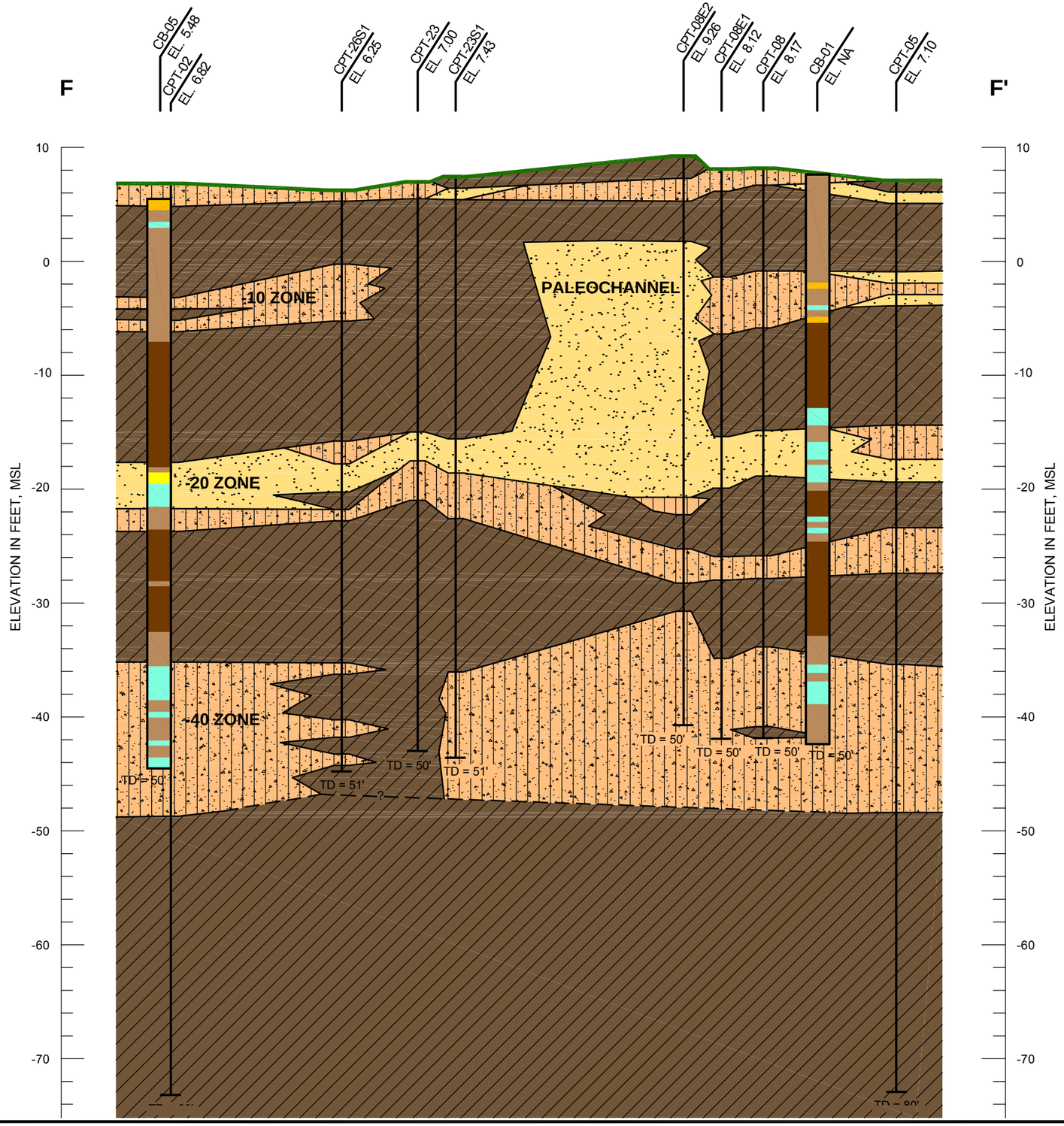
Title: **CROSS-SECTION E - E'**

Project: Malone Service Co. Superfund Site

Client: **Malone Cooperating Parties**

Scale:	Drawn by:	Date:	Project No.:	File Name:	Figure:
As Shown	SJF	2-1-06	25008093	Cross-Sects A-B-C-D-E-F-G.dwg	15
	Chk'd by: JK	Date: 2-1-06			

K:\ELM\B11102_Malone_Remedial Investigation & Feasibility Study_03\Drawings\Acad\Drawings\RI-FS PLAN\Fig 11 thru 17 - Cross-Sects A-B-C-D-E-F-G.dwgE-E' Feb 03, 2006 - 10:13am



LEGEND:

CPT-02 EL. 6.82 — DESIGNATION NUMBER WITH GROUND SURFACE ELEVATION, FEET

CPT - CONE PENETROMETER TEST SOIL BORING

CB - CORRELATION SOIL BORING

MW - MONITORING WELL

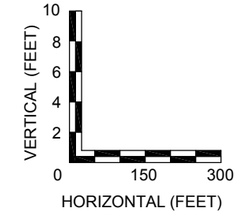
TD = 25' — TOTAL DEPTH IN FEET (BELOW GROUND SURFACE)

MONITORING WELL / CORRELATION BORING LITHOLOGY - DEC 2005

- CLAY (CH)
- SILTY CLAY / SANDY CLAY (CL)
- SILT / CLAYEY SILT (ML)
- CLAYEY SAND (SC)
- SILTY SAND (SM)

PREVIOUS INTERPRETED LITHOLOGY

- CLAY (CH / CL)
- CLAY / SAND / SILT MIXTURES AND/OR INTERBEDDED (CL / SC / SM / ML)
- SAND (SP / SW)



VERTICAL EXAGGERATION = 30 x

Note:

1. Ground surface elevations were surveyed by Wilson Surveying Group, Inc.

URS
9801 WESTHEIMER, SUITE 500
HOUSTON, TEXAS 77042
PH: (713) 914-6699
FAX: (713) 789-8404

Title: **CROSS-SECTION F - F'**

Project: Malone Service Co. Superfund Site

Client: **Malone Cooperating Parties**

Scale:	Drawn by:	Date:	Project No.:	File Name:	Figure:
As Shown	SJF	2-1-06	25008093	Cross-Sects A-B-C-D-E-F-G.dwg	16
	Chk'd by: JK	Date: 2-1-06			

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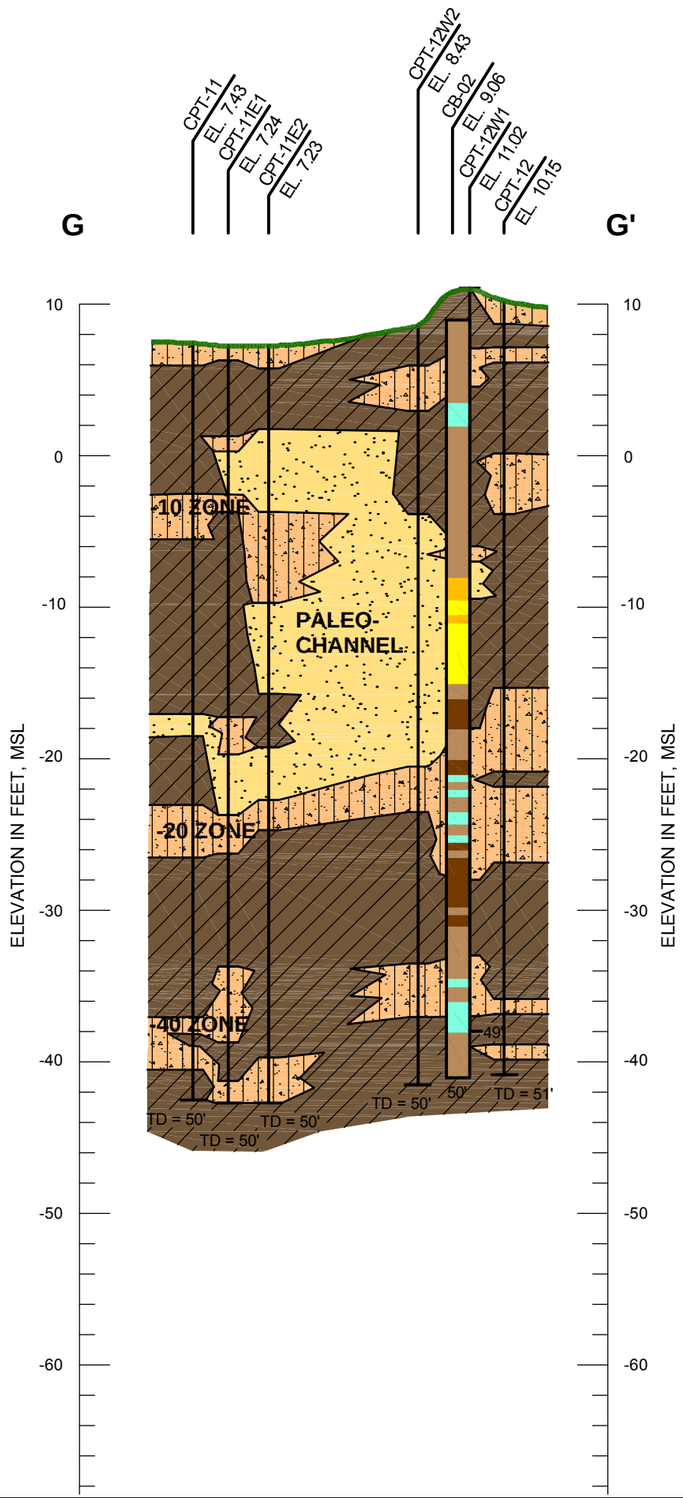


LEGEND:

CPT-02
EL 6.82

DESIGNATION NUMBER WITH
GROUND SURFACE ELEVATION, FEET

CPT - CONE PENETROMETER TEST
SOIL BORING

CB - CORRELATION SOIL BORING

MW - MONITORING WELL

TD = 25'

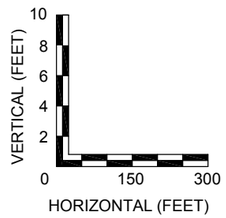
TOTAL DEPTH IN FEET
(BELOW GROUND SURFACE)

MONITORING WELL /
CORRELATION BORING
LITHOLOGY - DEC 2005

- CLAY (CH)
- SILTY CLAY / SANDY CLAY (CL)
- SILT / CLAYEY SILT (ML)
- CLAYEY SAND (SC)
- SILTY SAND (SM)

PREVIOUS
INTERPRETED LITHOLOGY

- CLAY (CH / CL)
- CLAY / SAND / SILT MIXTURES AND/OR INTERBEDDED (CL / SC / SM / ML)
- SAND (SP / SW)



VERTICAL EXAGGERATION = 30 x

Note:

1. Ground surface elevations were surveyed by Wilson Surveying Group, Inc.

URS
9801 WESTHEIMER, SUITE 500
HOUSTON, TEXAS 77042
PH: (713) 914-6699
FAX: (713) 789-8404

Title: **CROSS-SECTION G - G'**

Project: Malone Service Co. Superfund Site

Client: **Malone Cooperating Parties**

Scale:	Drawn by:	Date:	Project No.:	File Name:	Figure:
As Shown	SJF	2-1-06	25008093	Cross-Sects A-B-C-D-E-F-G.dwg	17
	Chk'd by: JK	Date: 2-1-06			

K:\ELM\B11102_Malone_Remedial Investigation & Feasibility Study_03\Drawings\Acad\Drawings\RI-FS PLAN\Fig 11 thru 17 - Cross-Sects A-B-C-D-E-F-G.dwgG-G' Feb 03, 2006 - 10:14am

SOURCE:

AERIAL PHOTO FROM 2003-2004 H-GAC AND GDC DIGITAL ORTHOPHOTO COVERAGE AREA.
NAD 83, TEXAS STATE PLANE, SOUTH CENTRAL ZONE COORDINATE SYSTEM.

SAMPLE LOCATIONS WERE SURVEYED BY THE WILSON SURVEY GROUP, INC.

0 300 600

APPROXIMATE SCALE IN FEET

MALONE SERVICE CO.
SUPERFUND SITE

URS
9801 Westheimer
Suite 500
Houston, Texas 77042
PH: (713) 914-6699
FAX: (713) 914-8404

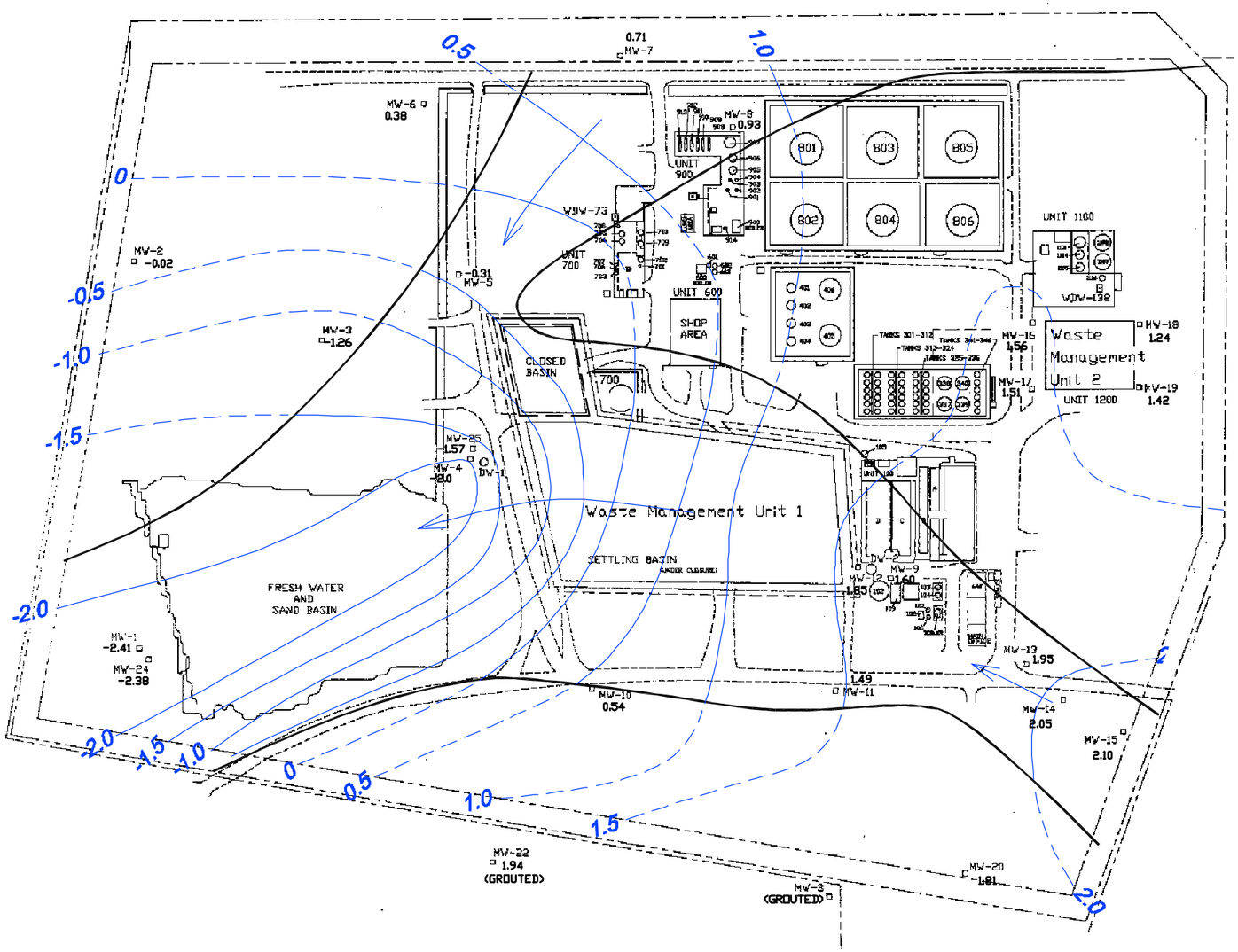
SCALE:	DRAWN BY: SJF	DATE: 2-1-06
AS SHOWN	CHKD BY: BB	DATE: 2-1-06

PALEOCHANNEL LOCATION

FILE No.
Paleochannel Location.dwg

FIGURE No.
18

K:\ELM\611102_Malone_Remedial Investigation & Feasibility Study_05\Drawings\Acad\Drawings\RI-FS PLAN\Fig 18 - Paleochannel Location.dwg\Layout1 Feb 01, 2006 - 3:39pm



LEGEND

- PROPERTY BOUNDARY
- CLOSED SOLID WASTE MANAGEMENT UNIT
- DEEP WELL LOCATION
- MONITOR WELL LOCATION
- 2.10 - WATER LEVEL ELEVATION (FT MSL)
- BURIED PALEOSTREAM CHANNEL AQUIFER
- 2.0 - POTENTIOMETRIC CONTOURS (FT MSL) CONTOURS DASHED (INFERRED) OUTSIDE CHANNEL
- GROUNDWATER FLOW DIRECTION

SOURCE: DATA OBTAINED FROM CLIENT AND WAS ORIGINATED BY ENVIRONMENTAL CONSULTING ASSOCIATES AUSTIN, TEXAS. DATED SEPT. 1989.

0 300 600
SCALE IN FEET

MALONE SERVICE CO.
SUPERFUND SITE

URS
9801 Westheimer
Suite 500
Houston, Texas 77042
PH: (713) 914-6699
FAX: (713) 914-8404

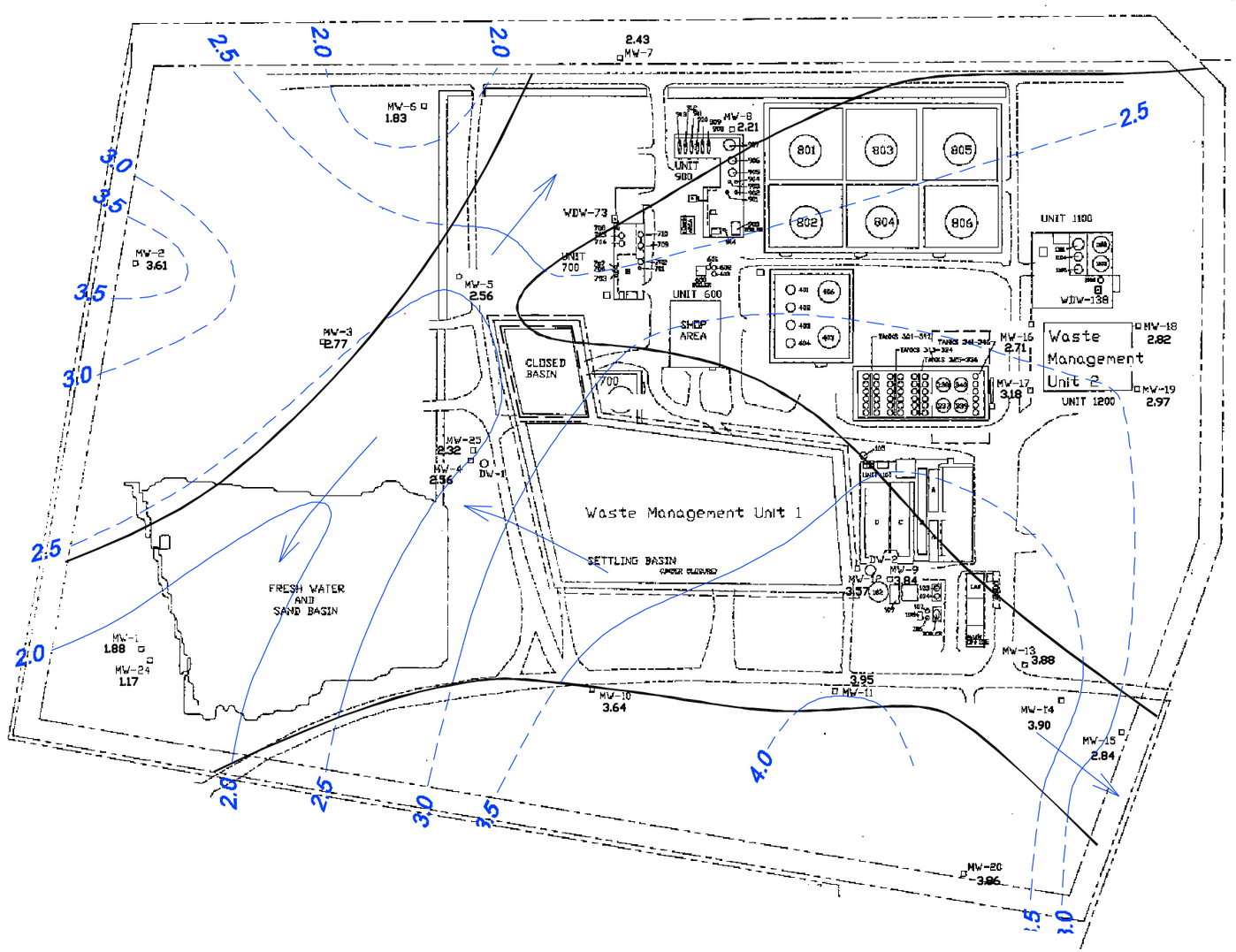
SCALE: 1" = 300'
DRAWN BY: SJF
CHKD. BY:
DATE: 2-10-04
DATE:

POTENTIOMETRIC CONTOUR MAP SEPTEMBER 1986

FILE NO.
POTENTIO-CONTOURS

FIGURE NO.
20

K:\ELM\811102_Malone_Remedial Investigation & Feasibility Study_03\Drawings\Acad\Drawings\RI-FS PLAN\Fig 20 - 1986 Potentiometric Surface.dwg 1986-CONTOURS Feb 01, 2006 - 4:44pm



LEGEND

- PROPERTY BOUNDARY
- CLOSED SOLID WASTE MANAGEMENT UNIT
- DW-1 - DEEP WELL LOCATION
- MW-19 - MONITOR WELL LOCATION
- 1.83 - WATER LEVEL ELEVATION (FT MSL)
- BURIED PALEOSTREAM CHANNEL AQUIFER
- 2.0 - POTENTIOMETRIC CONTOURS (FT MSL) CONTOURS DASHED (INFERRED) OUTSIDE CHANNEL
- GROUNDWATER FLOW DIRECTION

SOURCE: DATA OBTAINED FROM CLIENT AND WAS ORIGINATED BY ENVIRONMENTAL CONSULTING ASSOCIATES AUSTIN, TEXAS. DATED SEPT. 1989.
WATER LEVEL ELEVATIONS FROM MSC 1994 ANNUAL GROUND WATER SUMMARY.

0 300 600
SCALE IN FEET

MALONE SERVICE CO.
SUPERFUND SITE

URS
9801 Westheimer
Suite 500
Houston, Texas 77042
PH: (713) 914-6699
FAX: (713) 914-8404

SCALE:	DRAWN BY:	SJF	DATE:	2-10-04
1" = 300'	CHKD. BY:		DATE:	

POTENTIOMETRIC CONTOUR MAP
FEBRUARY 1994

FILE NO.
POTENTIO-CONTOURS

FIGURE NO.
21

K:\ELM\811102_Malone_Remedial Investigation & Feasibility Study_03\Drawings\Acad\Drawings\RI-FS PLAN\Fig 21 - 1994 Potentiometric Surface.dwg1994-CONTOURS Feb 01, 2006 - 4:42pm

K:\ELM\811102_Malone_Remedial Investigation & Feasibility Study_03\Drawings\Acad\Drawings\RI-FS PLAN\Fig 22 - Potentiometric Surface- August 2005.dwg Layout1 Feb 01, 2006 - 5:28pm

SOURCE:

AERIAL PHOTO FROM 2003-2004 H-GAC AND GDC DIGITAL ORTHOPHOTO COVERAGE AREA, NAD 83 TEXAS STATE PLANE COORDINATE SYSTEM.

SAMPLE LOCATIONS WERE SURVEYED BY THE WILSON SURVEY GROUP, INC.

MALONE SERVICE CO. SUPERFUND SITE

URS
9801 Westheimer
Suite 500
Houston, Texas 77042
PH: (713) 914-6699
FAX: (713) 914-8404

SCALE:	DRAWN BY: SJF	DATE: 2-1-06
AS SHOWN	CHKD BY: BB	DATE: 2-1-06

POTENTIOMETRIC SURFACE MAP AUGUST 2, 2005

FILE No. POTENTIOMETRIC AUG 2005.dwg

FIGURE No. 22

SOURCE:

AERIAL PHOTO FROM 2003-2004 H-GAC AND GDC DIGITAL ORTHOPHOTO COVERAGE AREA. NAD 83, TEXAS STATE PLANE, SOUTH CENTRAL ZONE COORDINATE SYSTEM.

SAMPLE LOCATIONS WERE SURVEYED BY THE WILSON SURVEY GROUP, INC.

0 300 600

APPROXIMATE SCALE IN FEET

MALONE SERVICE CO. SUPERFUND SITE

URS
9801 Westheimer
Suite 500
Houston, Texas 77042
PH: (713) 914-6699
FAX: (713) 914-8404

SCALE:	DRAWN BY: SJF	DATE: 2-3-06
AS SHOWN	CHKD BY: BB	DATE: 2-3-06

POTENTIOMETRIC SURFACE MAP JANUARY 9, 2006

FILE No. Potentiometric Surface Jan 2006.dwg

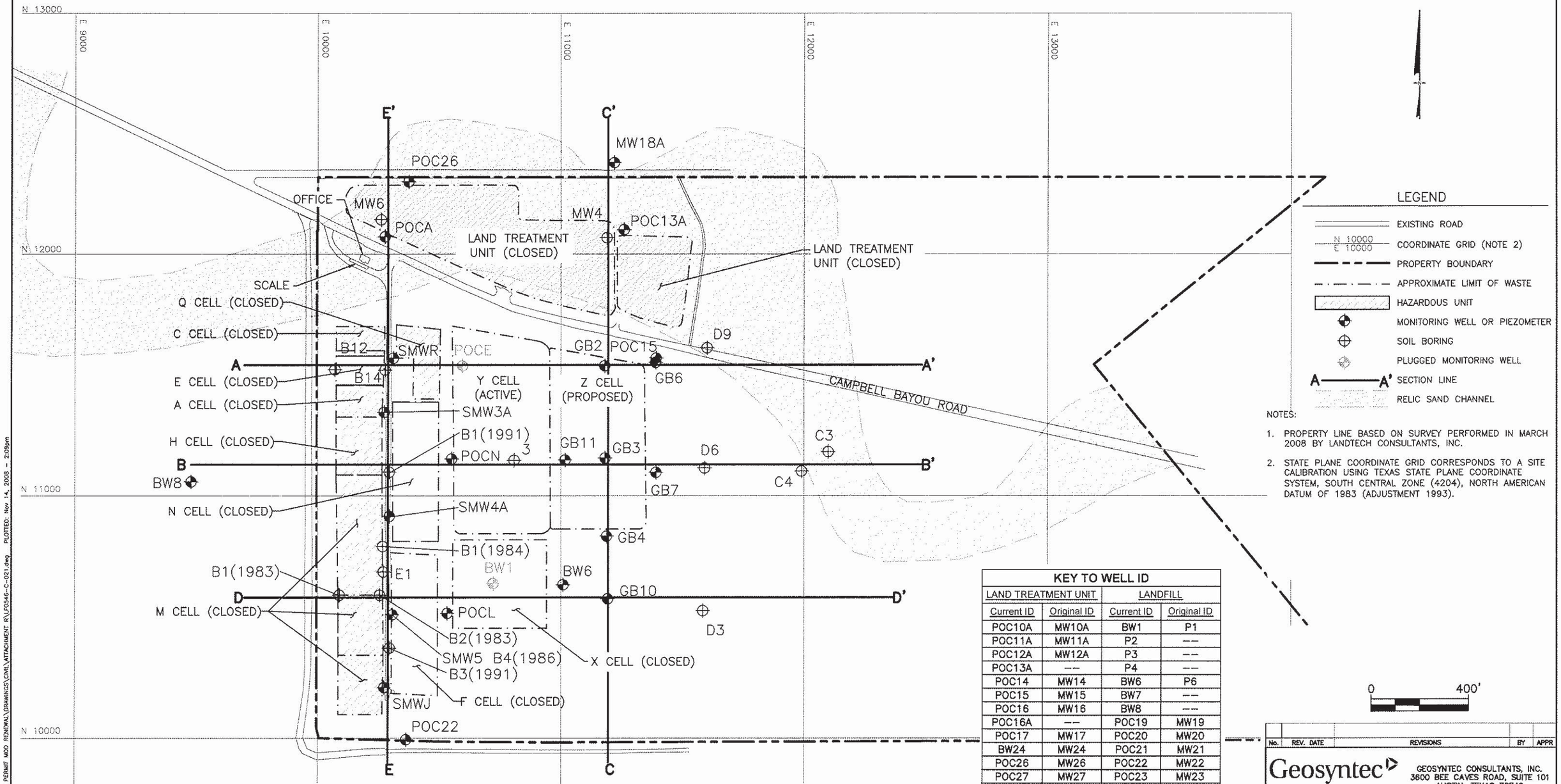
FIGURE No. 23

K:\ELM\811102_Malone_Remedial Investigation & Feasibility Study_03\Drawings\Acad\Drawings\RI-FS PLAN\Fig 23 - Potentiometric Surface- January 2006.dwgLayout1 Feb 03, 2006 - 3:53pm

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Appendix 1.3
Drawings from Geosyntec Consultants (2008)



LEGEND

- EXISTING ROAD
- N 10000 / E 10000 — COORDINATE GRID (NOTE 2)
- PROPERTY BOUNDARY
- APPROXIMATE LIMIT OF WASTE
- HAZARDOUS UNIT
- MONITORING WELL OR PIEZOMETER
- SOIL BORING
- PLUGGED MONITORING WELL
- A — A' SECTION LINE
- RELIC SAND CHANNEL

NOTES:

1. PROPERTY LINE BASED ON SURVEY PERFORMED IN MARCH 2008 BY LANDTECH CONSULTANTS, INC.
2. STATE PLANE COORDINATE GRID CORRESPONDS TO A SITE CALIBRATION USING TEXAS STATE PLANE COORDINATE SYSTEM, SOUTH CENTRAL ZONE (4204), NORTH AMERICAN DATUM OF 1983 (ADJUSTMENT 1993).

0 400'

KEY TO WELL ID

LAND TREATMENT UNIT		LANDFILL	
Current ID	Original ID	Current ID	Original ID
POC10A	MW10A	BW1	P1
POC11A	MW11A	P2	---
POC12A	MW12A	P3	---
POC13A	---	P4	---
POC14	MW14	BW6	P6
POC15	MW15	BW7	---
POC16	MW16	BW8	---
POC16A	---	POC19	MW19
POC17	MW17	POC20	MW20
BW24	MW24	POC21	MW21
POC26	MW26	POC22	MW22
POC27	MW27	POC23	MW23
BW28A	---	POCE	---
POCA	---	POCF	---
POCB	---	POCG	---
POCC	---	POCH	---
POCD	---	POCI	---
MW10	---	POCK	---
MW18A	---	POCL	---
MW29	---	POCM	---
MW11	---	POCN	---
MW12	---	SMWJ	---
MW13	---	SMWR	---
MW28	---	SMW3A	---
		SMW4A	---
		SMW5	P5
		MW25	---

No.	REV. DATE	REVISIONS	BY	APPR

Geosyntec consultants
GEOSYNTEC CONSULTANTS, INC.
3600 BEE CAVES ROAD, SUITE 101
AUSTIN, TEXAS 78746
PHONE: 512.451.4003

GCA GULF COAST WASTE DISPOSAL AUTHORITY —CAMPBELL BAYOU—

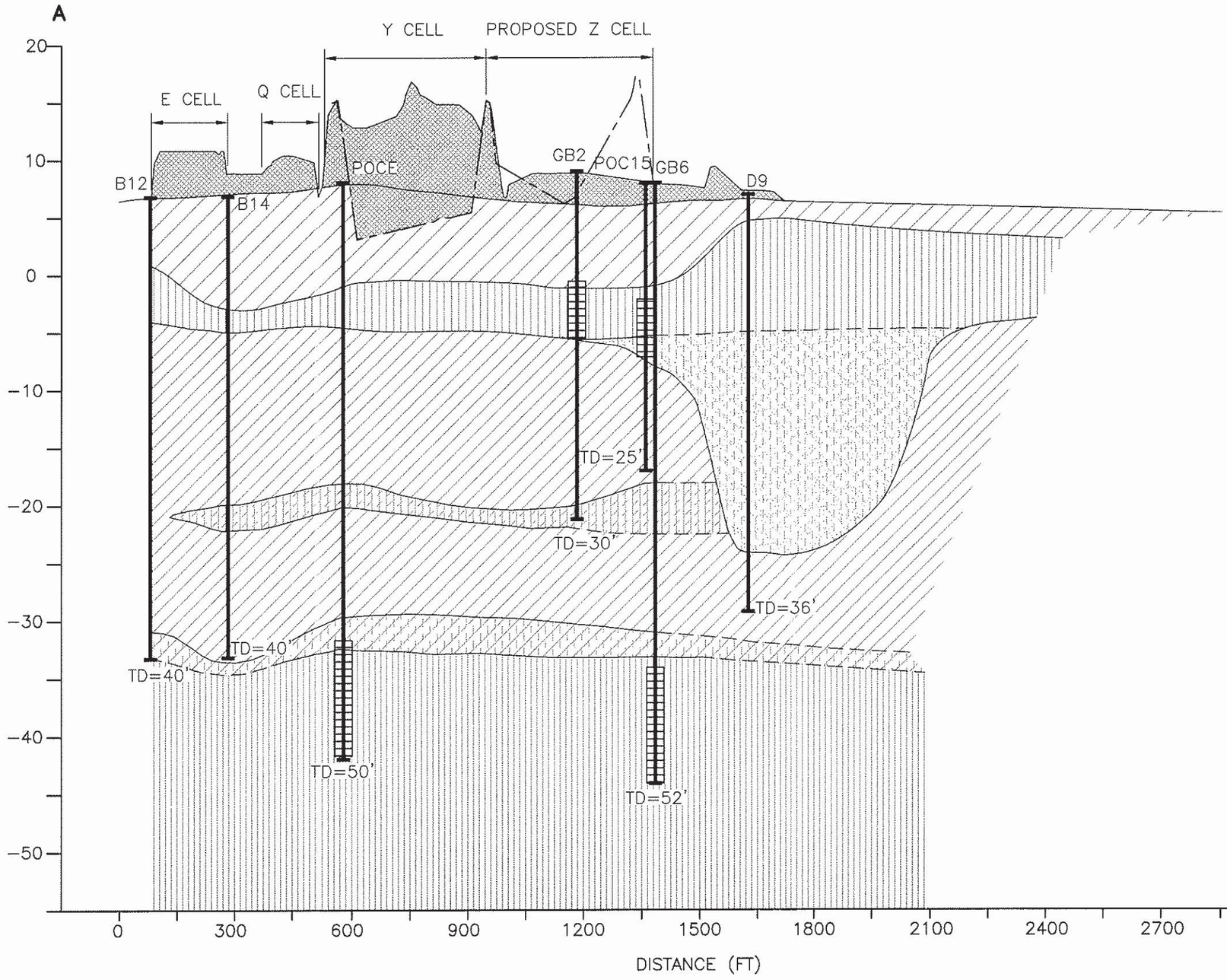
SCALE: 1" = 400'	DRAWN BY: JJV	ENG BY: BG
DATE: NOVEMBER 2008	CHECKED BY: MS	APPR BY: EBD

GEOLOGICAL SECTIONS LOCATION MAP

PROJECT #:

R-19

DRAWING: Austin P:\CAD\Campbell Bayou Facility_Permit\GCA\LF PERMIT MOD RENEWAL\DRAWINGS\CIVIL\ATTACHMENT R\LF0546-C-021.dwg PLOTTED: Nov 14, 2008 - 2:09pm



LEGEND

- FILL
- STRATUM I – SHALLOW CLAY
- STRATUM II – SHALLOW SILT
- STRATUM IIa – SAND CHANNEL (LTU AQUIFER)
- STRATUM III – LOWER CLAY
  - –DISCONTINUOUS SILT LENS
  - –TRANSITION CLAY TO SILT
- STRATUM IV – LOWER SILT
- INFERRED (EXTRAPOLATED) STRATUM CONTACT
- Y AND Z CELLS TOP OF LINER
- B3 — WELL / PIEZOMETER CASING OR BORING TRACE
- WELL / PIEZOMETER SCREEN INTERVAL
- TD=60' — TOTAL DEPTH (FT)

0 300' HORIZONTAL SCALE 1" = 300'

0 10' VERTICAL SCALE 1" = 10'

NOTES:

1. THE SOIL BORING/ROCK CORING INFORMATION IS REPRESENTATIVE OF SUBSURFACE CONDITIONS AT THE RESPECTIVE BORING LOCATIONS. SUBSURFACE CONDITIONS INTERPOLATED BETWEEN BORINGS ARE ESTIMATED, BASED ON ACCEPTED SOIL ENGINEERING PRINCIPALS AND GEOLOGIC JUDGMENT.
2. GROUND SURFACE ELEVATIONS IN UNDISTURBED AREAS ARE TAKEN FROM TOPOGRAPHIC MAP AS PRESENTED ON DRAWING Q-2 OF ATTACHMENT Q. IN AREAS WHERE SOIL OR WASTE FILLING HAS TAKEN PLACE, PREVIOUS GROUND SURFACE ELEVATIONS OF DISTURBED AREA WERE DERIVED USING CONTOUR MAP DEVELOPED USING PRE-LANDFILL USGS QUADRANGLES, AND BORING LOG SURFACE ELEVATIONS.
3. PORTIONS OF CROSS SECTIONS MAY BE EXTRAPOLATED BENEATH OR BETWEEN AVAILABLE BORING INFORMATION BASED ON GEOLOGIC JUDGMENT OF SUBSURFACE TRENDS CONSIDERING INTERSECTING CROSS SECTIONS.

No.	REV. DATE	REVISIONS	BY	APPR

Geosyntec consultants
GEOSYNTEC CONSULTANTS, INC.
3600 BEE CAVES ROAD, SUITE 101
AUSTIN, TEXAS 78746
PHONE: 512.451.4003

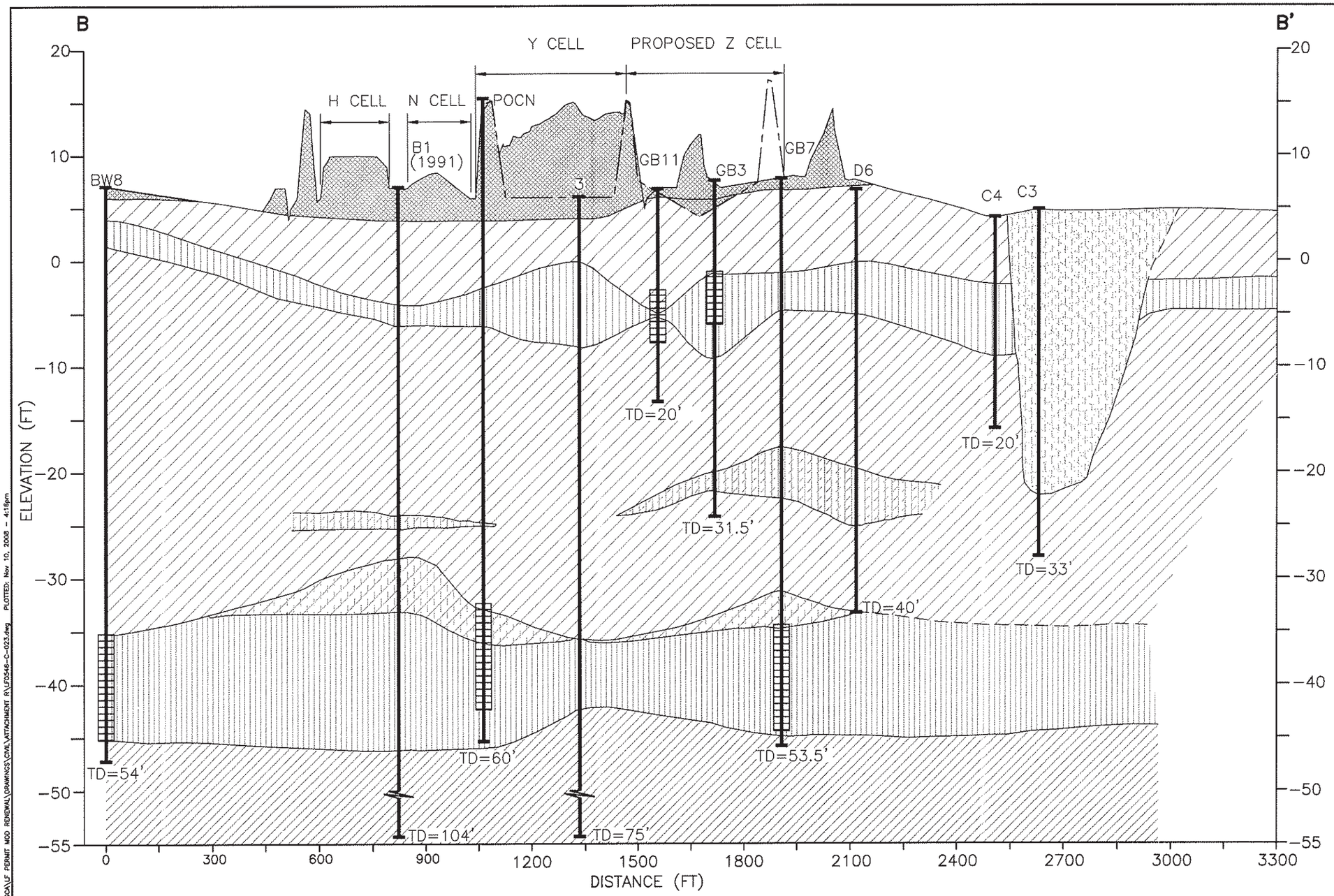
GCA GULF COAST WASTE DISPOSAL AUTHORITY –CAMPBELL BAYOU–

SCALE: AS SHOWN	DRAWN BY: JJV	ENG BY: BG
DATE: NOVEMBER 2008	CHECKED BY: MS	APPR BY: EBD

GEOLOGICAL SECTION A–A'

PROJECT #: R–20

DRAWING: Austin P:\CADD\Campbell Bayou Facility_Permit\GCA LF PERMIT MOD. RENEWAL\DRAWINGS\CIVIL\ATTACHMENT R\LF0546-C-022.dwg PLOTTED: Nov 10, 2008 - 4:15pm



LEGEND

- FILL
- STRATUM I – SHALLOW CLAY
- STRATUM II – SHALLOW SILT
- STRATUM IIa – SAND CHANNEL (LTU AQUIFER)
- STRATUM III – LOWER CLAY
  - –DISCONTINUOUS SILT LENS
  - –TRANSITION CLAY TO SILT
- STRATUM IV – LOWER SILT
- STRATUM V – DEEP CLAY
- INFERRED (EXTRAPOLATED) STRATUM CONTACT
- Y AND Z CELLS TOP OF LINER
- B3 WELL / PIEZOMETER CASING OR BORING TRACE
- WELL / PIEZOMETER SCREEN INTERVAL
- TD=60' TOTAL DEPTH (FT)

0 300' HORIZONTAL SCALE 1" = 300'

0 10' VERTICAL SCALE 1" = 10'

NOTES:

1. THE SOIL BORING/ROCK CORING INFORMATION IS REPRESENTATIVE OF SUBSURFACE CONDITIONS AT THE RESPECTIVE BORING LOCATIONS. SUBSURFACE CONDITIONS INTERPOLATED BETWEEN BORINGS ARE ESTIMATED, BASED ON ACCEPTED SOIL ENGINEERING PRINCIPALS AND GEOLOGIC JUDGMENT.
2. GROUND SURFACE ELEVATIONS IN UNDISTURBED AREAS ARE TAKEN FROM TOPOGRAPHIC MAP AS PRESENTED ON DRAWING Q–2 OF ATTACHMENT Q. IN AREAS WHERE SOIL OR WASTE FILLING HAS TAKEN PLACE, PREVIOUS GROUND SURFACE ELEVATIONS OF DISTURBED AREA WERE DERIVED USING CONTOUR MAP DEVELOPED USING PRE–LANDFILL USGS QUADRANGLES, AND BORING LOG SURFACE ELEVATIONS.
3. PORTIONS OF CROSS SECTIONS MAY BE EXTRAPOLATED BENEATH OR BETWEEN AVAILABLE BORING INFORMATION BASED ON GEOLOGIC JUDGMENT OF SUBSURFACE TRENDS CONSIDERING INTERSECTING CROSS SECTIONS.

No.	REV. DATE	REVISIONS	BY	APPR

Geosyntec consultants
GEOSYNTEC CONSULTANTS, INC.
3600 BEE CAVES ROAD, SUITE 101
AUSTIN, TEXAS 78746
PHONE: 512.451.4003

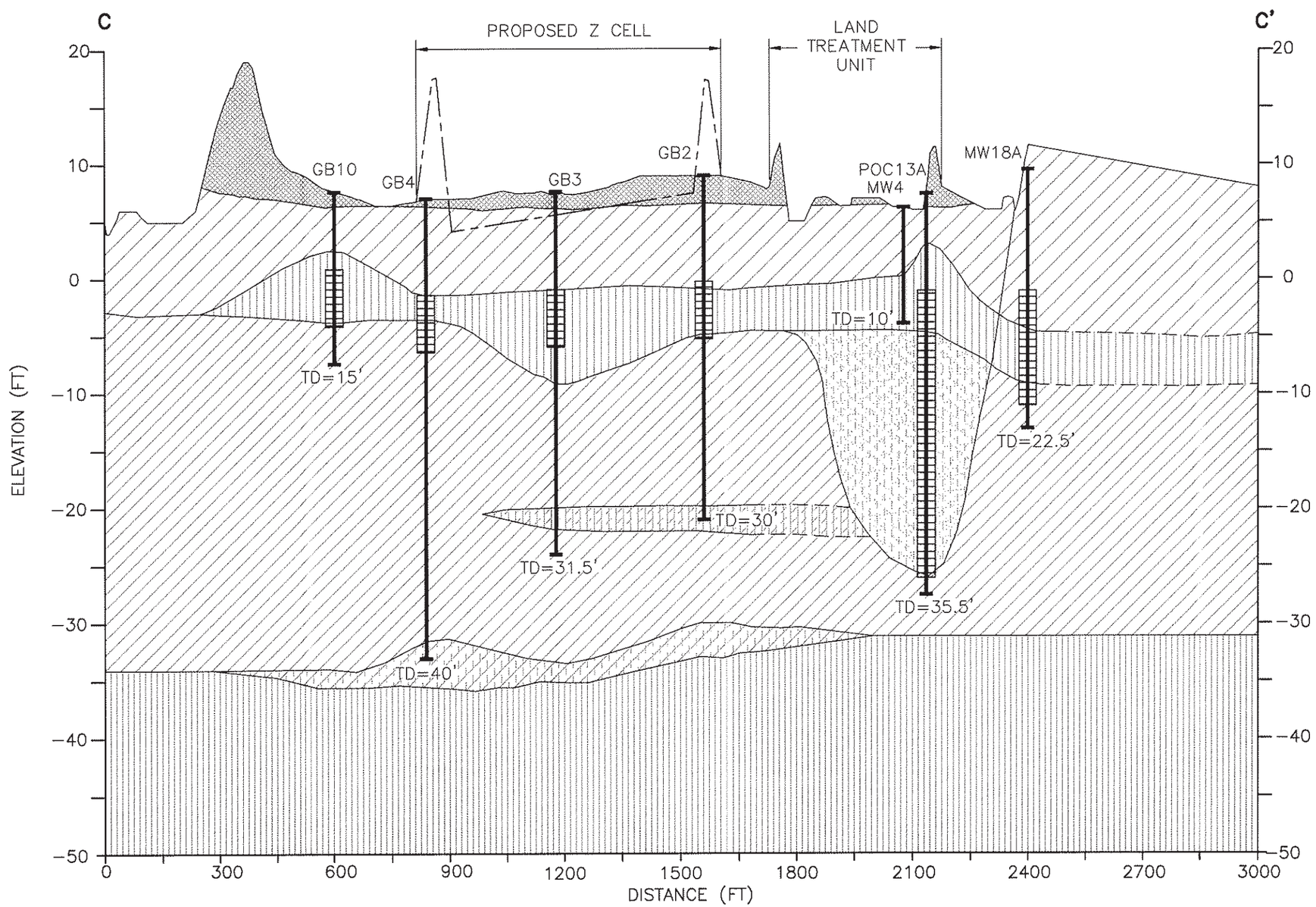
GCA GULF COAST WASTE DISPOSAL AUTHORITY –CAMPBELL BAYOU–

SCALE: AS SHOWN	DRAWN BY: JJV	ENG BY: BG
DATE: NOVEMBER 2008	CHECKED BY: MS	APPR BY: EBD

GEOLOGICAL SECTION B–B'

PROJECT #: R–21

DRAWING: Austin P:\CADD\Campbell Bayou Facility_Permit\GCA\LF PERMIT MOD RENEWAL\DRAWINGS\CIVIL\ATTACHMENT R\LF0546–C–023.dwg PLOTTED: Nov 10, 2008 – 4:18pm



LEGEND

- FILL
- STRATUM I – SHALLOW CLAY
- STRATUM II – SHALLOW SILT
- STRATUM IIa – SAND CHANNEL (LTU AQUIFER)
- STRATUM III – LOWER CLAY
  - –DISCONTINUOUS SILT LENS
  - –TRANSITION CLAY TO SILT
- STRATUM IV – LOWER SILT
- INFERRED (EXTRAPOLATED) STRATUM CONTACT
- Y AND Z CELLS TOP OF LINER

B3 – WELL / PIEZOMETER CASING OR BORING TRACE

WELL / PIEZOMETER SCREEN INTERVAL

TD=60' – TOTAL DEPTH (FT)

0 300' HORIZONTAL SCALE 1" = 300'

0 10' VERTICAL SCALE 1" = 10'

NOTES:

1. THE SOIL BORING/ROCK CORING INFORMATION IS REPRESENTATIVE OF SUBSURFACE CONDITIONS AT THE RESPECTIVE BORING LOCATIONS. SUBSURFACE CONDITIONS INTERPOLATED BETWEEN BORINGS ARE ESTIMATED, BASED ON ACCEPTED SOIL ENGINEERING PRINCIPALS AND GEOLOGIC JUDGMENT.
2. GROUND SURFACE ELEVATIONS IN UNDISTURBED AREAS ARE TAKEN FROM TOPOGRAPHIC MAP AS PRESENTED ON DRAWING Q-2 OF ATTACHMENT Q. IN AREAS WHERE SOIL OR WASTE FILLING HAS TAKEN PLACE, PREVIOUS GROUND SURFACE ELEVATIONS OF DISTURBED AREA WERE DERIVED USING CONTOUR MAP DEVELOPED USING PRE-LANDFILL USGS QUADRANGLES, AND BORING LOG SURFACE ELEVATIONS.
3. PORTIONS OF CROSS SECTIONS MAY BE EXTRAPOLATED BENEATH OR BETWEEN AVAILABLE BORING INFORMATION BASED ON GEOLOGIC JUDGMENT OF SUBSURFACE TRENDS CONSIDERING INTERSECTING CROSS SECTIONS.

No.	REV. DATE	REVISIONS	BY	APPR

Geosyntec consultants
GEOSYNTEC CONSULTANTS, INC.
3600 BEE CAVES ROAD, SUITE 101
AUSTIN, TEXAS 78746
PHONE: 512.451.4003

GCA GULF COAST WASTE DISPOSAL AUTHORITY –CAMPBELL BAYOU–

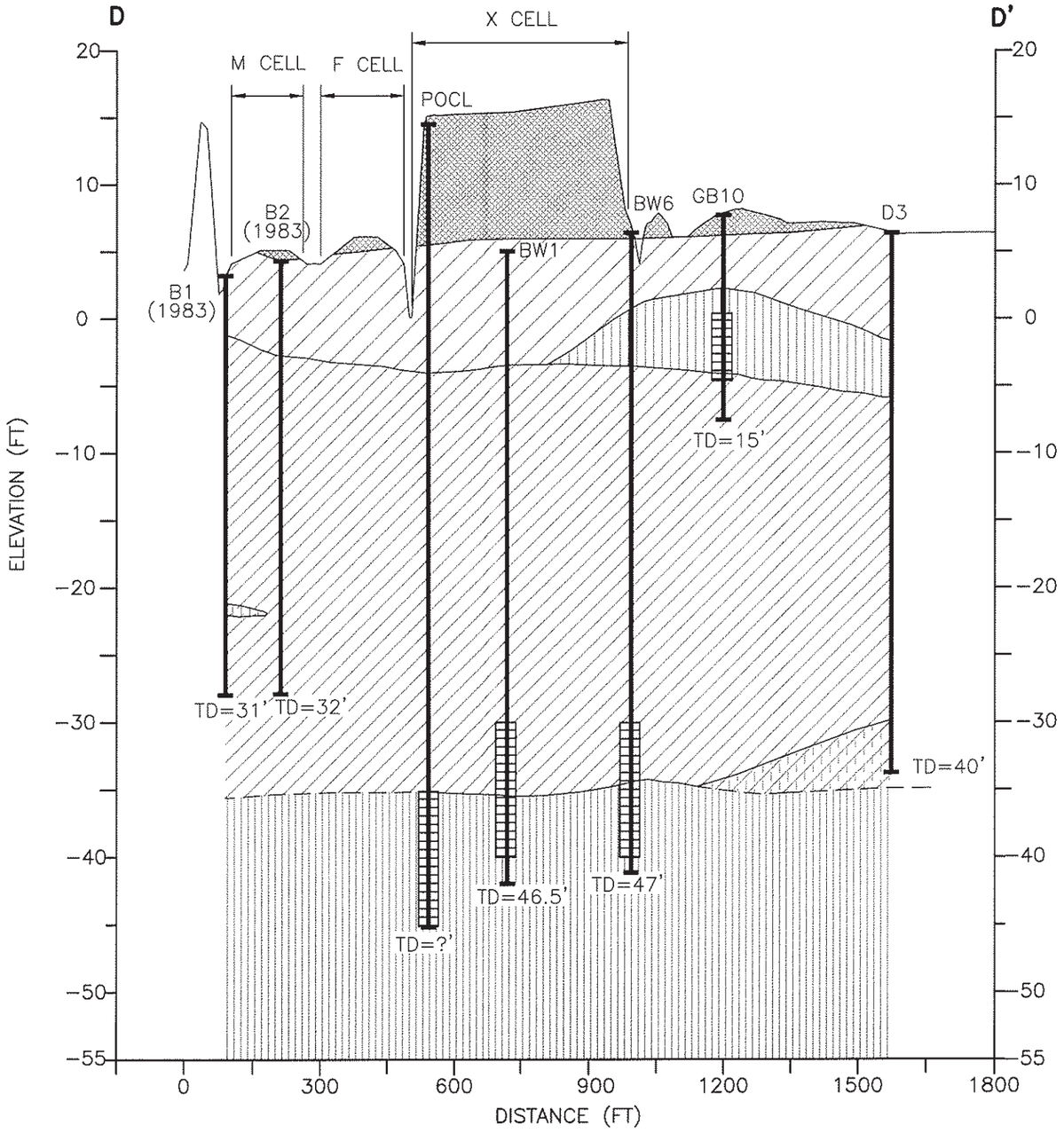
SCALE: AS SHOWN	DRAWN BY: JJV	ENG BY: BG
DATE: NOVEMBER 2008	CHECKED BY: MS	APPR BY: EBD

GEOLOGICAL SECTION C–C'

PROJECT #:

R–22

DRAWING: Austin P:\CAD\Campbell Bayou Facility_Permit\02A\LF PERMIT MOD RENEWAL\DRAWINGS\CIVIL\ATTACHMENT R\U70546-C-024.dwg PLOTTED: Nov 10, 2008 - 4:35pm



LEGEND

- FILL
- STRATUM I – SHALLOW CLAY
- STRATUM II – SHALLOW SILT
- STRATUM III – LOWER CLAY
  - –DISCONTINUOUS SILT LENS
  - –TRANSITION CLAY TO SILT
- STRATUM IV – LOWER SILT
- INFERRED (EXTRAPOLATED) STRATUM CONTACT

B3 — WELL / PIEZOMETER CASING OR BORING TRACE

WELL / PIEZOMETER SCREEN INTERVAL

TD=60' TOTAL DEPTH (FT)

0 300'
HORIZONTAL SCALE 1" = 300'

0 10'
VERTICAL SCALE 1" = 10'

NOTES:

1. THE SOIL BORING/ROCK CORING INFORMATION IS REPRESENTATIVE OF SUBSURFACE CONDITIONS AT THE RESPECTIVE BORING LOCATIONS. SUBSURFACE CONDITIONS INTERPOLATED BETWEEN BORINGS ARE ESTIMATED, BASED ON ACCEPTED SOIL ENGINEERING PRINCIPALS AND GEOLOGIC JUDGMENT.
2. GROUND SURFACE ELEVATIONS IN UNDISTURBED AREAS ARE TAKEN FROM TOPOGRAPHIC MAP AS PRESENTED ON DRAWING Q–2 OF ATTACHMENT Q. IN AREAS WHERE SOIL OR WASTE FILLING HAS TAKEN PLACE, PREVIOUS GROUND SURFACE ELEVATIONS OF DISTURBED AREA WERE DERIVED USING CONTOUR MAP DEVELOPED USING PRE–LANDFILL USGS QUADRANGLES, AND BORING LOG SURFACE ELEVATIONS.
3. PORTIONS OF CROSS SECTIONS MAY BE EXTRAPOLATED BENEATH OR BETWEEN AVAILABLE BORING INFORMATION BASED ON GEOLOGIC JUDGMENT OF SUBSURFACE TRENDS CONSIDERING INTERSECTING CROSS SECTIONS.

No.	REV. DATE	REVISIONS	BY	APPR

Geosyntec consultants
GEOSYNTEC CONSULTANTS, INC.
3600 BEE CAVES ROAD, SUITE 101
AUSTIN, TEXAS 78746
PHONE: 512.451.4003

GCA GULF COAST WASTE DISPOSAL AUTHORITY –CAMPBELL BAYOU–

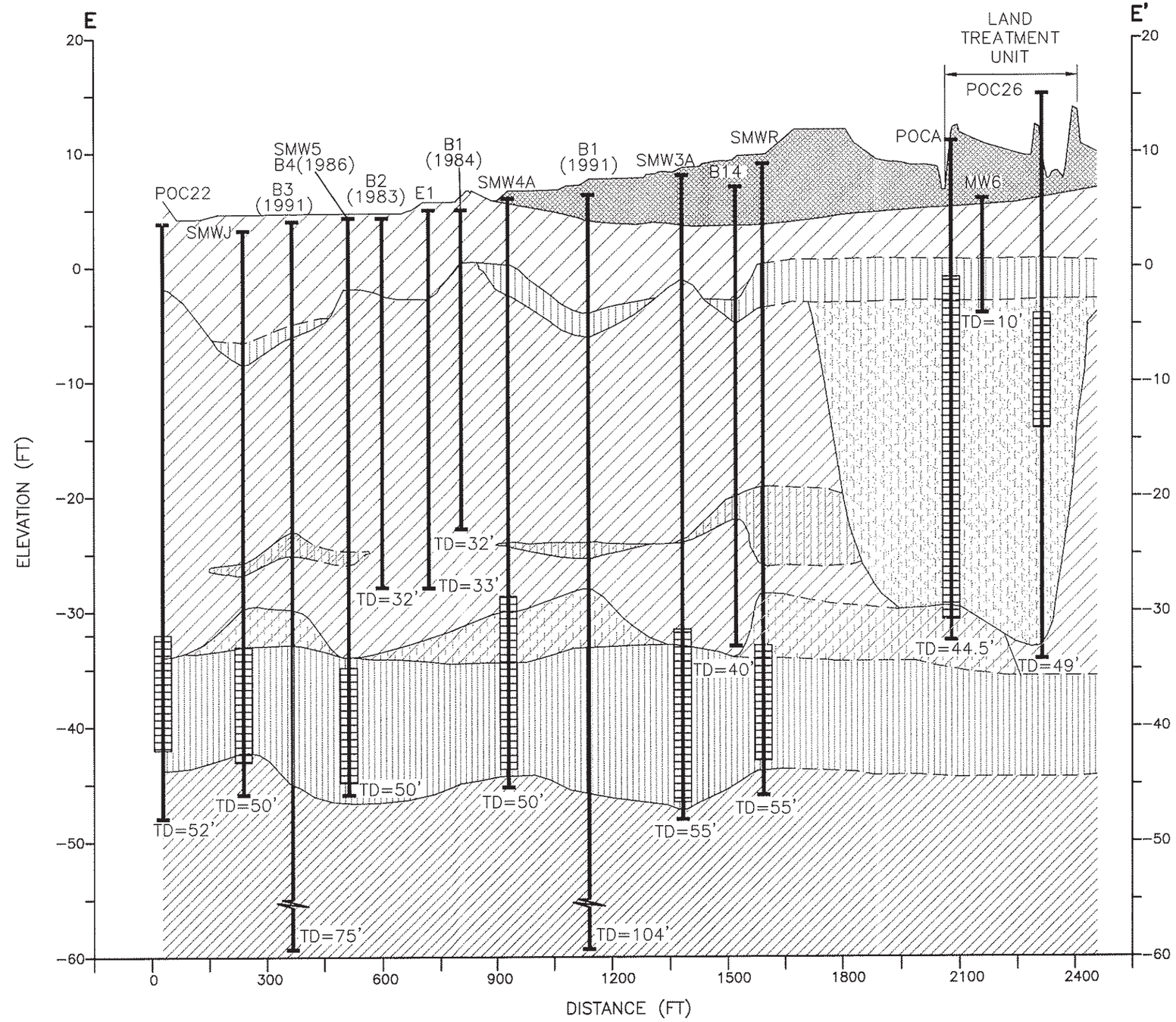
SCALE: AS SHOWN	DRAWN BY: JJV	ENG BY: BG
DATE: NOVEMBER 2008	CHECKED BY: MS	APPR BY: EBD

GEOLOGICAL SECTION D–D'

PROJECT #:

R–23

DRAWING: Austin P:\CADD\Campbell Bayou Facility_Permit\GCA\LF PERMIT MOD RENEWAL\DRAWINGS\CIVIL\ATTACHMENT R\LF0546-C-025.dwg PLOTTED: Nov 10, 2008 - 4:36pm



LEGEND

- FILL
- STRATUM I – SHALLOW CLAY
- STRATUM II – SHALLOW SILT
- STRATUM IIa – SAND CHANNEL (LTU AQUIFER)
- STRATUM III – LOWER CLAY
- –DISCONTINUOUS SILT LENS
- –TRANSITION CLAY TO SILT
- STRATUM V – DEEP CLAY
- INFERRED (EXTRAPOLATED) STRATUM CONTACT

B3 – WELL / PIEZOMETER CASING OR BORING TRACE

WELL / PIEZOMETER SCREEN INTERVAL

TOTAL DEPTH (FT)

TD=60'

0 300' HORIZONTAL SCALE 1" = 300'

0 10' VERTICAL SCALE 1" = 10'

NOTES:

1. THE SOIL BORING/ROCK CORING INFORMATION IS REPRESENTATIVE OF SUBSURFACE CONDITIONS AT THE RESPECTIVE BORING LOCATIONS. SUBSURFACE CONDITIONS INTERPOLATED BETWEEN BORINGS ARE ESTIMATED, BASED ON ACCEPTED SOIL ENGINEERING PRINCIPALS AND GEOLOGIC JUDGMENT.
2. GROUND SURFACE ELEVATIONS IN UNDISTURBED AREAS ARE TAKEN FROM TOPOGRAPHIC MAP AS PRESENTED ON DRAWING Q-2 OF ATTACHMENT Q. IN AREAS WHERE SOIL OR WASTE FILLING HAS TAKEN PLACE, PREVIOUS GROUND SURFACE ELEVATIONS OF DISTURBED AREA WERE DERIVED USING CONTOUR MAP DEVELOPED USING PRE-LANDFILL USGS QUADRANGLES, AND BORING LOG SURFACE ELEVATIONS.
3. PORTIONS OF CROSS SECTIONS MAY BE EXTRAPOLATED BENEATH OR BETWEEN AVAILABLE BORING INFORMATION BASED ON GEOLOGIC JUDGMENT OF SUBSURFACE TRENDS CONSIDERING INTERSECTING CROSS SECTIONS.

No.	REV. DATE	REVISIONS	BY	APPR

Geosyntec consultants
GEOSYNTEC CONSULTANTS, INC.
3600 BEE CAVES ROAD, SUITE 101
AUSTIN, TEXAS 78746
PHONE: 512.451.4003

GCA GULF COAST WASTE DISPOSAL AUTHORITY –CAMPBELL BAYOU–

SCALE: AS SHOWN	DRAWN BY: JJV	ENG BY: BG
DATE: NOVEMBER 2008	CHECKED BY: MS	APPR BY: EBD

GEOLOGICAL SECTION E–E'

PROJECT #:

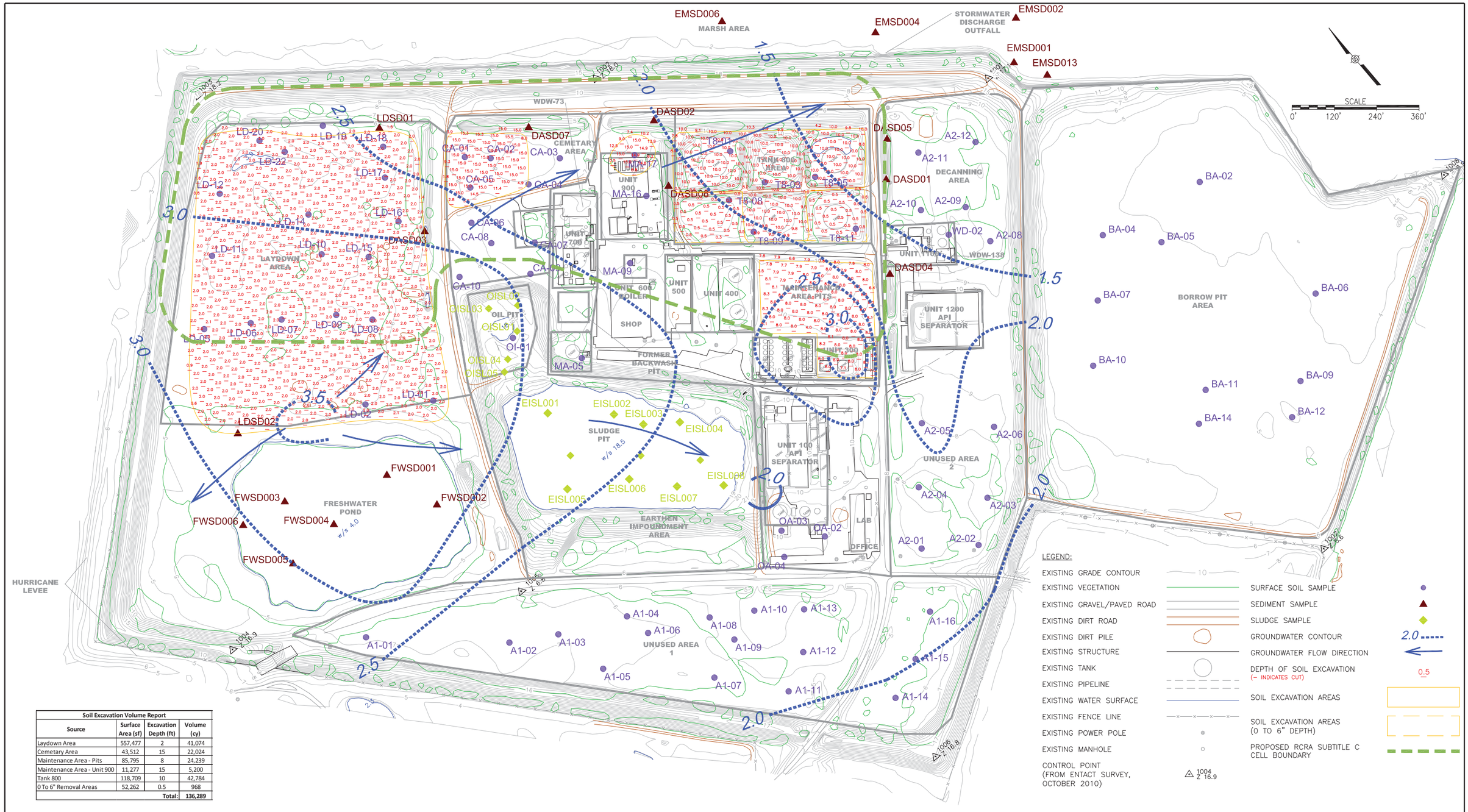
R–24

DRAWING: Austin P:\CADD\Campbell Bayou Facility_Permit\GCA\LF PERMIT MOD RENEWAL\DRAWINGS\CIVIL\ATTACHMENT R\LP0546-C-026.dwg PLOTTED: Nov 10, 2008 - 4:36pm

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Appendix 1.4
Drawings from Entact (2010)



Soil Excavation Volume Report			
Source	Surface Area (sf)	Excavation Depth (ft)	Volume (cy)
Laydown Area	557,477	2	41,074
Cemetary Area	43,512	15	22,024
Maintenance Area - Pits	85,795	8	24,239
Maintenance Area - Unit 900	11,277	15	5,200
Tank 800	118,709	10	42,784
0 To 6" Removal Areas	52,262	0.5	968
		Total:	136,289

LEGEND:

- EXISTING GRADE CONTOUR
- EXISTING VEGETATION
- EXISTING GRAVEL/PAVED ROAD
- EXISTING DIRT ROAD
- EXISTING DIRT PILE
- EXISTING STRUCTURE
- EXISTING TANK
- EXISTING PIPELINE
- EXISTING WATER SURFACE
- EXISTING FENCE LINE
- EXISTING POWER POLE
- EXISTING MANHOLE
- CONTROL POINT (FROM ENTACT SURVEY, OCTOBER 2010)
- SURFACE SOIL SAMPLE
- SEDIMENT SAMPLE
- SLUDGE SAMPLE
- GROUNDWATER CONTOUR
- GROUNDWATER FLOW DIRECTION
- DEPTH OF SOIL EXCAVATION (– INDICATES CUT)
- SOIL EXCAVATION AREAS
- SOIL EXCAVATION AREAS (0 TO 6" DEPTH)
- PROPOSED RCRA SUBTITLE C CELL BOUNDARY

NOTES:

1. THIS DRAWING WAS CREATED BASED ON PHOTOGRAMMATIC SURVEY DATA COLLECTED BY DALLAS AERIAL SURVEYS, INC. ON 10/29/10 AS REQUESTED BY ENTACT.
2. THE INFORMATION PRESENTED HEREIN IS CONFIDENTIAL IN NATURE AND IS NOT TO BE REPRODUCED OR RE-USED WITHOUT THE EXPRESSED WRITTEN PERMISSION OF ENTACT.

REV	DATE	BY	CHK'D	APR'VD	DESCRIPTION
A	11/23/10	HXD	GST	GST	ISSUED FOR PROPOSAL

ENTACT
699 South Friendswood Dr., Suite 101
Friendswood, Texas 77546
P: 281-996-9892

DRAWING NAME: FIG. 14 SOIL EXCAVATION AREAS

PROJECT NAME & LOCATION: MALONE SERVICE COMPANY SUPERFUND SITE, TEXAS CITY, TEXAS

DRAWN BY	H. DE LA O	APPROVED BY	G. TUNSTALL	REV	A
DATE	11-23-10	DATE	11-23-10	SHEET NO.	1 OF 1
DRAWING NO.	P7888-10-014	FIGURE NO.	14	PROJECT NO.	P7888

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

APPENDIX 2

Laboratory Results

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

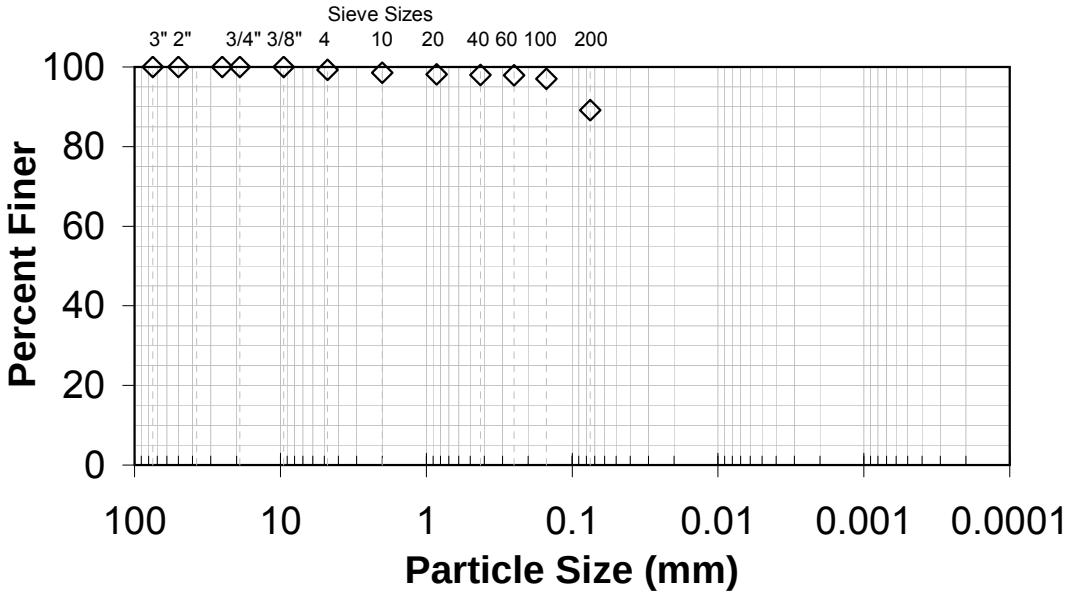
APPENDIX 2.1

Laboratory Results from Geosyntec (2008)

Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-1, 4'-6'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/17/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	99.3
No. 10 (2.00 mm)	98.6
No. 20 (850 μm)	98.2
No. 40 (425 μm)	98.0
No. 60 (250 μm)	97.9
No. 100 (150 μm)	97.0
No. 200 (75 μm)	89.1

Notes: Soil classifies as a fat clay (CH) in accordance with ASTM D 2487. The as received moisture content was 23.9% as determined by ASTM D 2166.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	58
Plastic Limit	16
Plastic Index	42
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

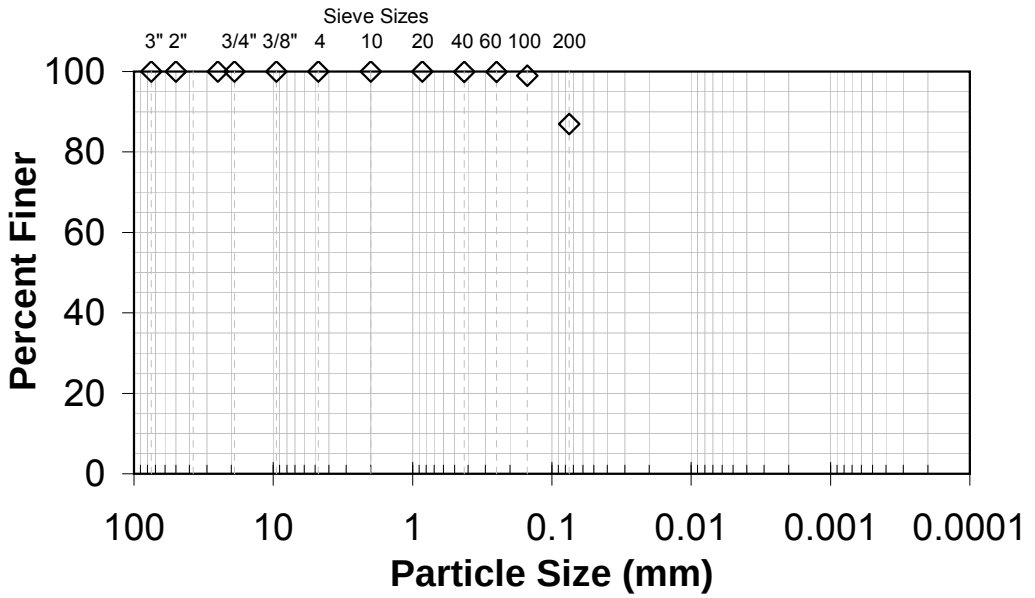
Cheng-Wei Chen, 04/19/2008
Review/Date

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested. TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material. TRI observes and maintains client confidentiality. TRI limits reproduction of this report, except in full, without prior approval of TRI.

Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-1, 10'-12'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/11/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	100.0
No. 10 (2.00 mm)	100.0
No. 20 (850 μm)	100.0
No. 40 (425 μm)	100.0
No. 60 (250 μm)	99.9
No. 100 (150 μm)	99.0
No. 200 (75 μm)	87.0

Notes: Soil classifies as a lean clay (CL) in accordance with ASTM D 2487. The as received moisture content was 22.7% as determined by ASTM D 2216.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	30
Plastic Limit	16
Plastic Index	14
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

Cheng-Wei Chen, 04/17/2008
Review/Date

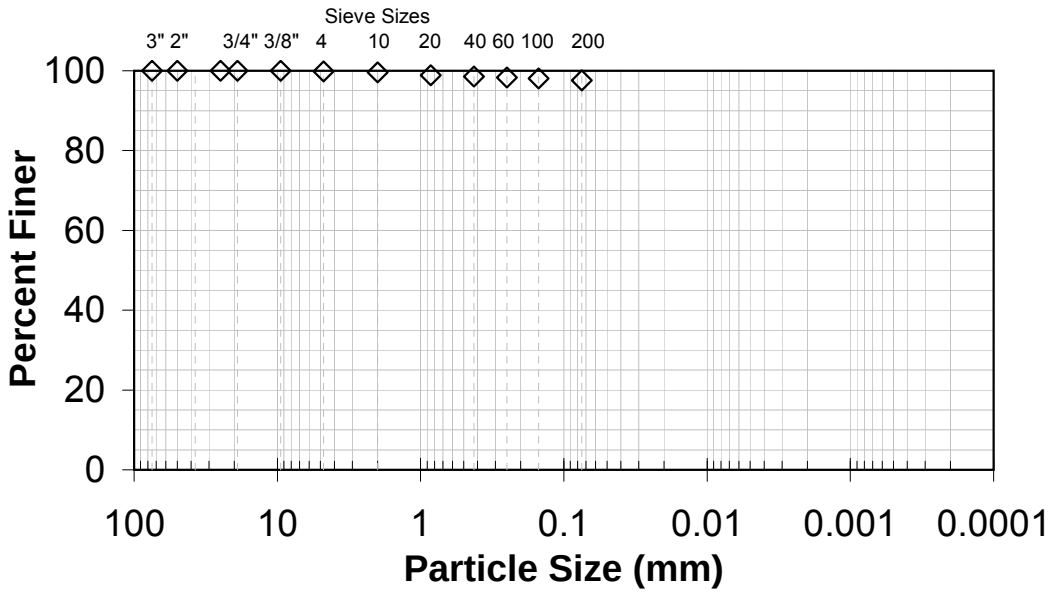
The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested. TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material. TRI observes and maintains client confidentiality. TRI limits reproduction of this report, except in full, without prior approval of TRI.

9063 Bee Caves Road □ Austin, TX 78733-6201 □ (512) 263-2101 □ (512) 263-2558 □ 1-800-880-TEST

Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-1, 20'-22'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/17/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	99.9
No. 10 (2.00 mm)	99.6
No. 20 (850 μm)	98.9
No. 40 (425 μm)	98.5
No. 60 (250 μm)	98.3
No. 100 (150 μm)	98.0
No. 200 (75 μm)	97.6

Notes: Soil classifies as a fat clay (CH) in accordance with ASTM D 2487. The as received moisture content was 32.3% as determined by ASTM D 2166.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	81
Plastic Limit	26
Plastic Index	55
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

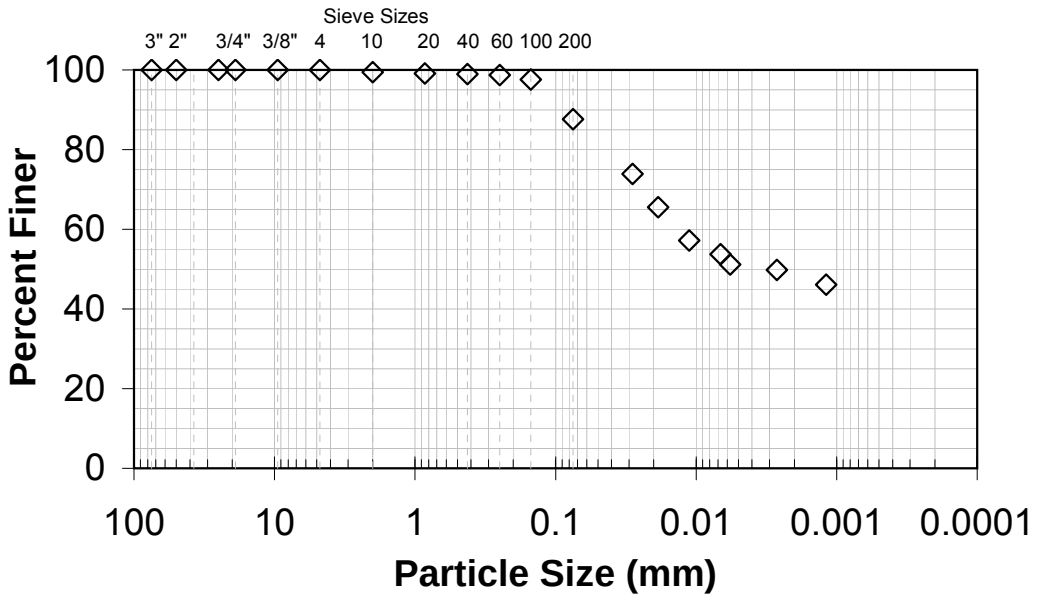
Cheng-Wei Chen, 04/18/2008
Review/Date

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested. TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material. TRI observes and maintains client confidentiality. TRI limits reproduction of this report, except in full, without prior approval of TRI.

Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-2, 6.5'-9'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/23/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	100.0
No. 10 (2.00 mm)	99.5
No. 20 (850 μm)	99.1
No. 40 (425 μm)	98.9
No. 60 (250 μm)	98.7
No. 100 (150 μm)	97.6
No. 200 (75 μm)	87.7
Hydrometer Analysis	
Particle Size	Percentage Passing (%)
0.074 mm	86.5
0.005 mm	50.6
0.001 mm	45.8

Notes: Soil classifies as a lean clay (CL) in accordance with ASTM D 2487. The as received moisture content was 18.5% as determined by ASTM D 2216.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	48
Plastic Limit	14
Plastic Index	34
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

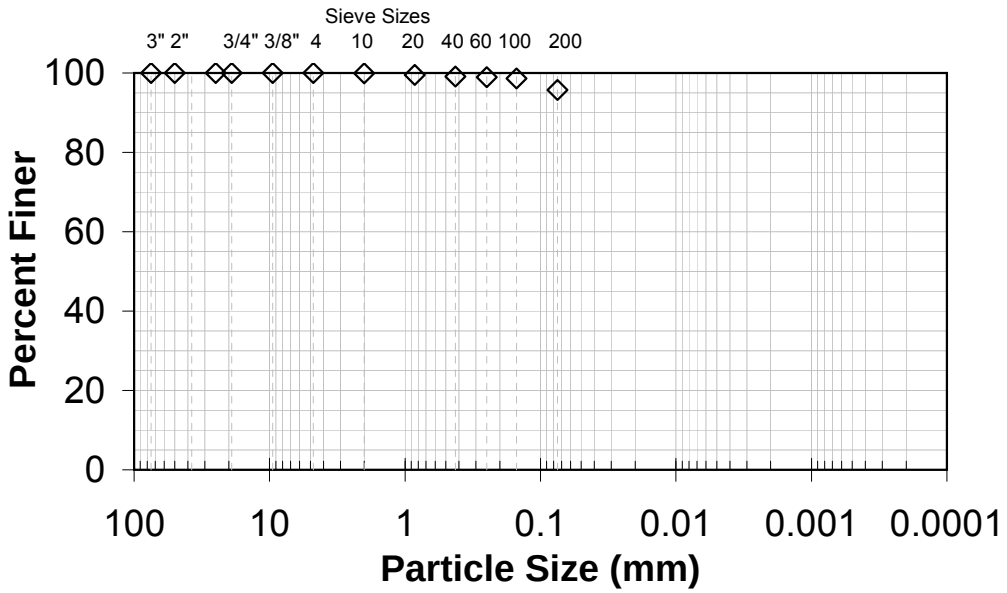
Cheng-Wei Chen, 04/28/08
Review/Date

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested. TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material. TRI observes and maintains client confidentiality. TRI limits reproduction of this report, except in full, without prior approval of TRI.

Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-2, 13'-15'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/11/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	100.0
No. 10 (2.00 mm)	99.9
No. 20 (850 μm)	99.5
No. 40 (425 μm)	99.1
No. 60 (250 μm)	98.9
No. 100 (150 μm)	98.7
No. 200 (75 μm)	95.8

Notes: Soil classifies as a lean clay (CL) in accordance with ASTM D 2487. The as received moisture content was 25.1% as determined by ASTM D 2216.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	27
Plastic Limit	18
Plastic Index	9
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

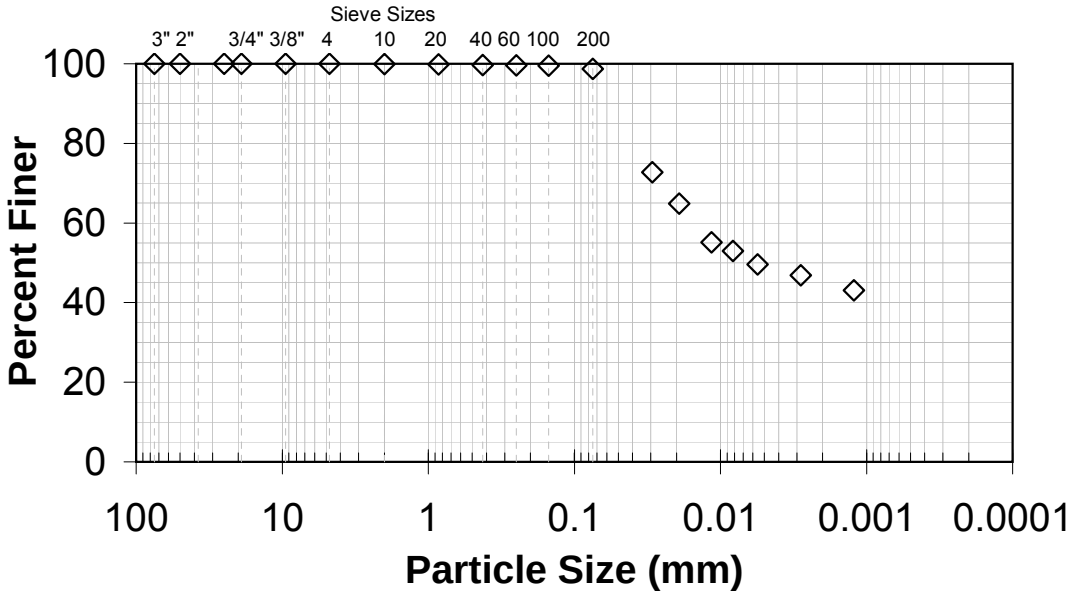
Cehng-Wei Chen, 04/16/2008
Review/Date

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested. TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material. TRI observes and maintains client confidentiality. TRI limits reproduction of this report, except in full, without prior approval of TRI.

Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-2, 19'-21.5'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 06/02/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	100.0
No. 10 (2.00 mm)	100.0
No. 20 (850 μm)	99.8
No. 40 (425 μm)	99.7
No. 60 (250 μm)	99.6
No. 100 (150 μm)	99.5
No. 200 (75 μm)	98.7
Hydrometer Analysis	
Particle Size	Percentage Passing (%)
0.074 mm	98.2
0.005 mm	49.2
0.001 mm	42.8

Notes: Soil classifies as a fat clay (CH) in accordance with ASTM D 2487. The as received moisture content was 33.9% as determined by ASTM D 2216.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	81
Plastic Limit	25
Plastic Index	56
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

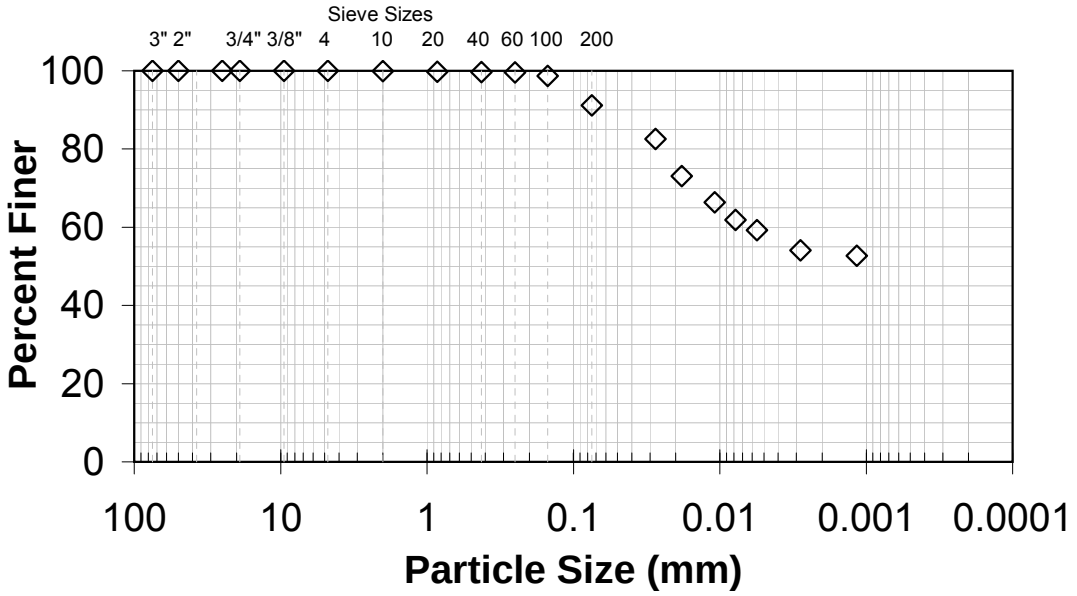
Cheng-Wei Chen, 6/04/08
Review/Date

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested. TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material. TRI observes and maintains client confidentiality. TRI limits reproduction of this report, except in full, without prior approval of TRI.

Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-3, 4'-6.5'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/18/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	100.0
No. 10 (2.00 mm)	99.9
No. 20 (850 μm)	99.8
No. 40 (425 μm)	99.7
No. 60 (250 μm)	99.6
No. 100 (150 μm)	98.7
No. 200 (75 μm)	91.1
Hydrometer Analysis	
Particle Size	Percentage Passing (%)
0.074 mm	89.6
0.005 mm	58.3
0.001 mm	52.1

Notes: Soil classifies as a lean clay (CL) in accordance with ASTM D 2487. The as received moisture content was 20.0% as determined by ASTM D 2216.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	49
Plastic Limit	15
Plastic Index	34
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

Cheng-Wei Chen, 04/28/08
Review/Date

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested. TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material. TRI observes and maintains client confidentiality. TRI limits reproduction of this report, except in full, without prior approval of TRI.

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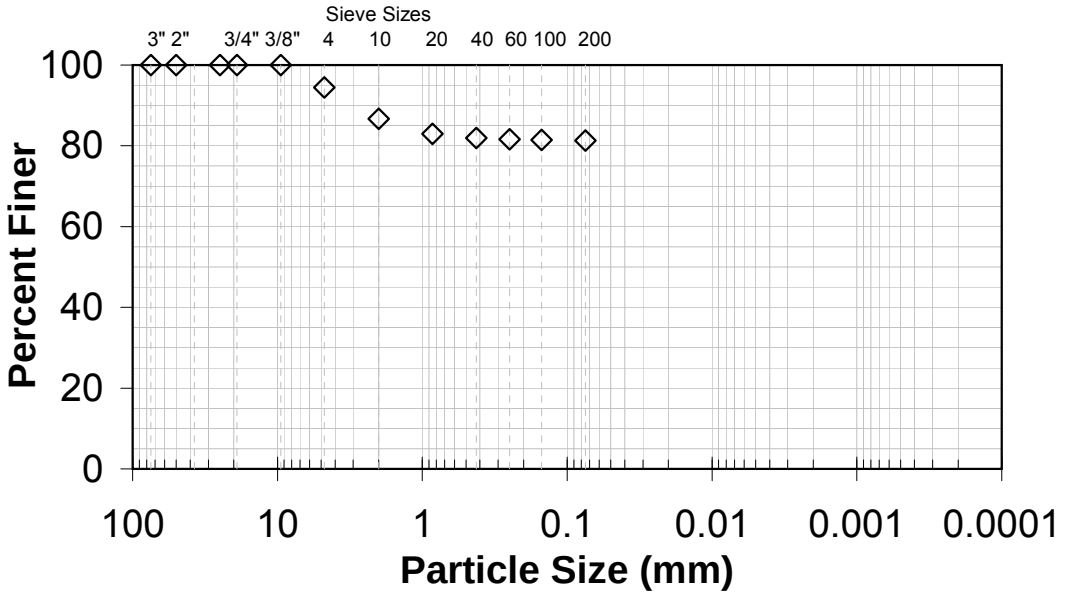
Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-3, 10.5'-13.0'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/16/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	94.5
No. 10 (2.00 mm)	86.7
No. 20 (850 μm)	83.0
No. 40 (425 μm)	81.9
No. 60 (250 μm)	81.6
No.100 (150 μm)	81.5
No. 200 (75 μm)	81.3

Notes: Soil classifies as a lean clay with sand (CL) in accordance with ASTM D 2487. The as received moisture content was 24.8% as determined by ASTM D 2216.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	32
Plastic Limit	17
Plastic Index	15
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

Cheng-Wei Chen, 04/21/2008
Review/Date

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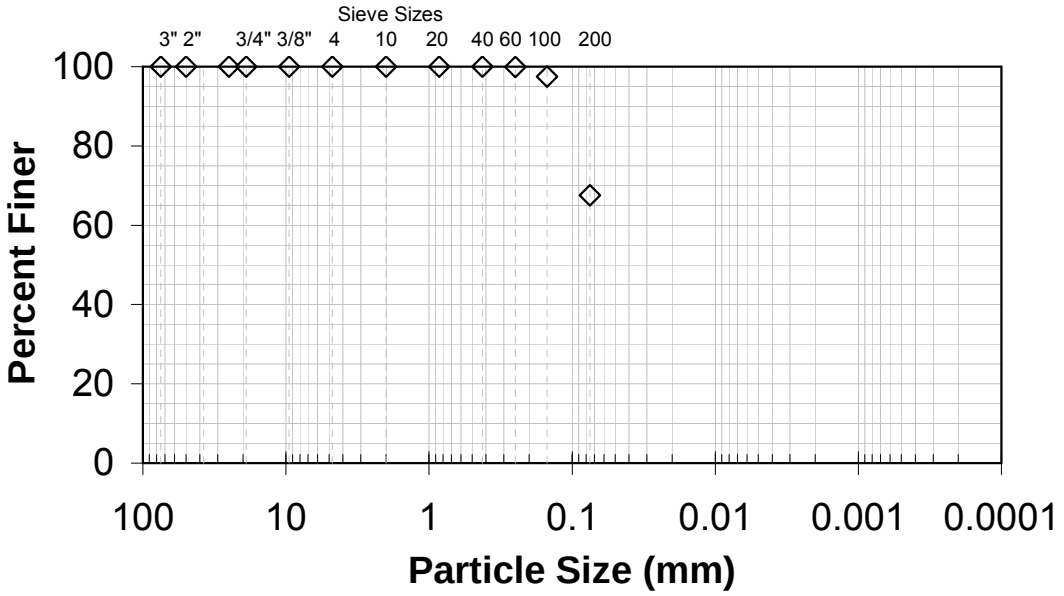
Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-3, 10.5'-13.0' (Silt)

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/23/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	100.0
No. 10 (2.00 mm)	100.0
No. 20 (850 μm)	100.0
No. 40 (425 μm)	100.0
No. 60 (250 μm)	99.9
No.100 (150 μm)	97.5
No. 200 (75 μm)	67.5

Notes: Soil classifies as a Silt with Sand (ML) in accordance with ASTM D 2487. The as received moisture content was 27.2% as determined by ASTM D 2216.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	NP
Plastic Limit	NP
Plastic Index	NP
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

Cheng-Wei Chen, 04/24/08
Review/Date

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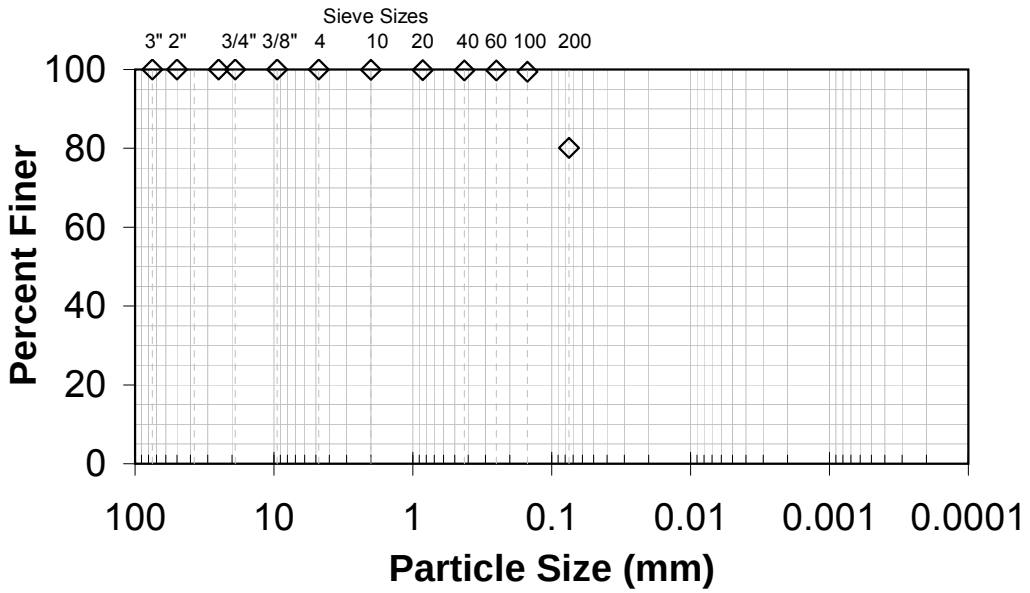
Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-3, 24.5'-27'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/24/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	100.0
No. 10 (2.00 mm)	100.0
No. 20 (850 μm)	99.9
No. 40 (425 μm)	99.8
No. 60 (250 μm)	99.7
No.100 (150 μm)	99.4
No. 200 (75 μm)	80.1

Notes: Soil classifies as a lean clay with sand (CL) in accordance with ASTM D 2487. The as received moisture content was 19.4% as determined by ASTM D 2216.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	43
Plastic Limit	15
Plastic Index	28
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

Cheng-Wei Chen, 04/29/08
Review/Date

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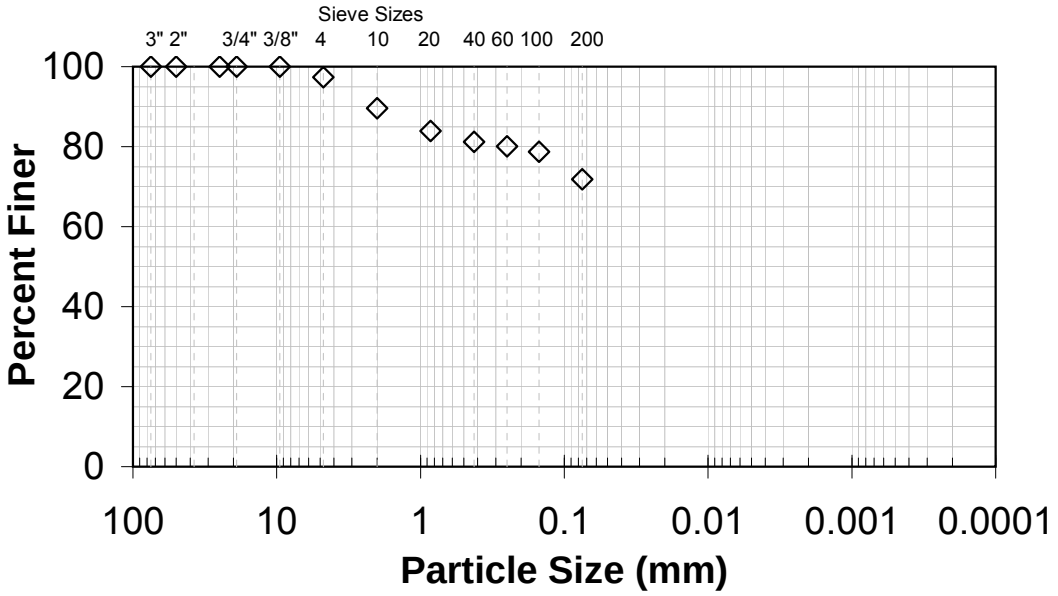
Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-4, 1'-6'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/17/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	97.4
No. 10 (2.00 mm)	89.6
No. 20 (850 μm)	84.0
No. 40 (425 μm)	81.2
No. 60 (250 μm)	80.1
No. 100 (150 μm)	78.8
No. 200 (75 μm)	71.9

Notes: Soil classifies as a lean clay with sand (CL) in accordance with ASTM D 2487. The as received moisture content was 17.5%, 22.6%, 22.5%, 16.9%, 17.2%, and 16.5% for the 1, 2, 3, 4, 5, and 6-ft depth samples respectively as determined by ASTM D 2166.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	40
Plastic Limit	14
Plastic Index	26
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

Cheng-Wei Chen, 04/18/2008
Review/Date

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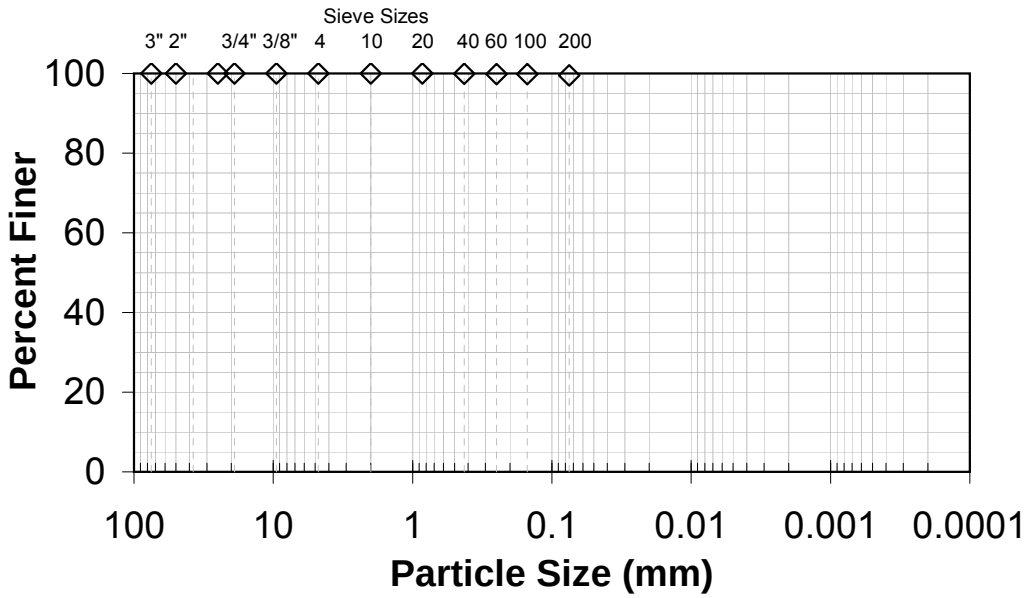
Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-4, 15'-17.5'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/21/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	100.0
No. 10 (2.00 mm)	100.0
No. 20 (850 μm)	100.0
No. 40 (425 μm)	99.9
No. 60 (250 μm)	99.9
No.100 (150 μm)	99.8
No. 200 (75 μm)	99.5

Notes: Soil classifies as a fat clay (CH) in accordance with ASTM D 2487. The as received moisture content was 28.5% as determined by ASTM D 2116.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	70
Plastic Limit	25
Plastic Index	45
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

Cheng-Wei Chen, 04/23/2008
Review/Date

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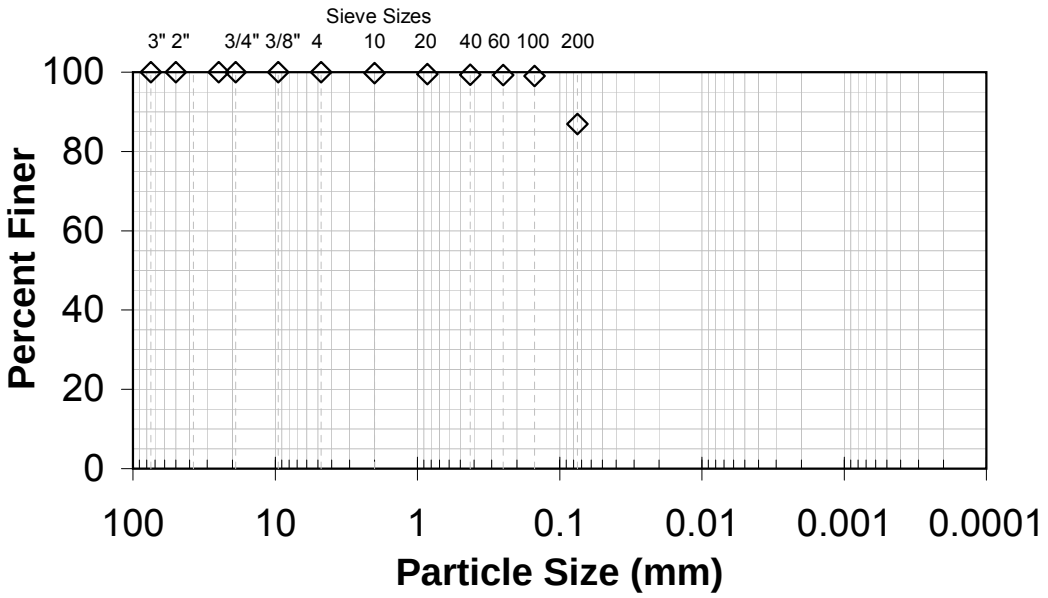
Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-4, 27.5'-30'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/22/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	100.0
No. 10 (2.00 mm)	99.8
No. 20 (850 μm)	99.5
No. 40 (425 μm)	99.4
No. 60 (250 μm)	99.3
No.100 (150 μm)	99.1
No. 200 (75 μm)	86.9

Notes: Soil classifies as a fat clay with sand (CH) in accordance with ASTM D 2487. The as received moisture content was 21.5% as determined by ASTM D 2116.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	50
Plastic Limit	15
Plastic Index	35
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

Cheng-Wei Chen, 04/23/2008
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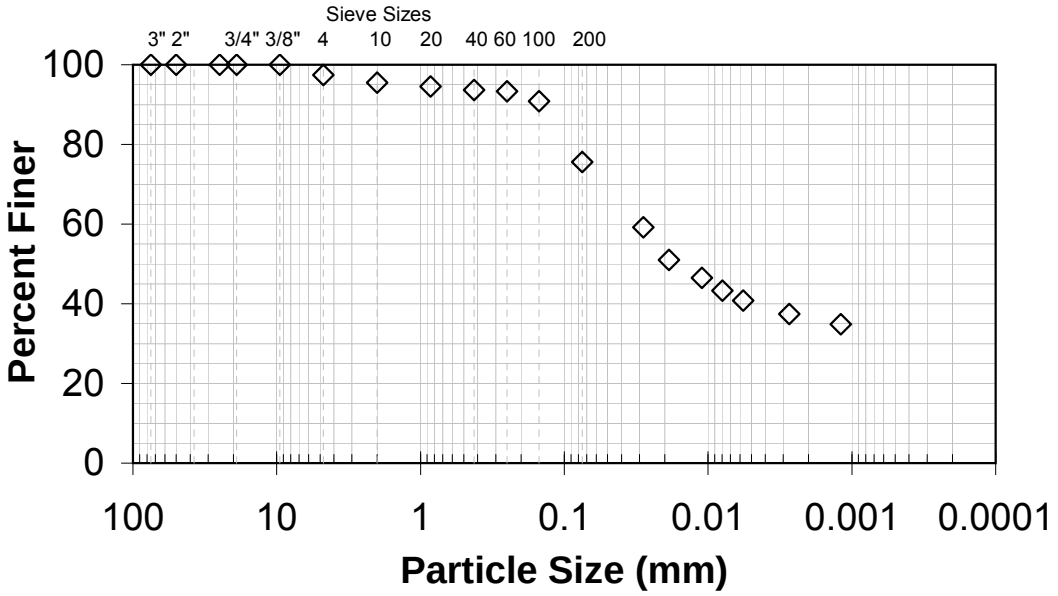
Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-5, 10'-12'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 06/02/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	97.4
No. 10 (2.00 mm)	95.5
No. 20 (850 μm)	94.5
No. 40 (425 μm)	93.7
No. 60 (250 μm)	93.3
No.100 (150 μm)	90.8
No. 200 (75 μm)	75.6
Hydrometer Analysis	
Particle Size	Percentage Passing (%)
0.074 mm	74.1
0.005 mm	40.2
0.001 mm	34.7

Notes: Soil classifies as a silt with sand (ML) in accordance with ASTM D 2487. The as received moisture content was 19.8% as determined by ASTM D 2116.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	NP
Plastic Limit	18
Plastic Index	NP
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

Cheng-Wei Chen, 6/04/08
Review/Date

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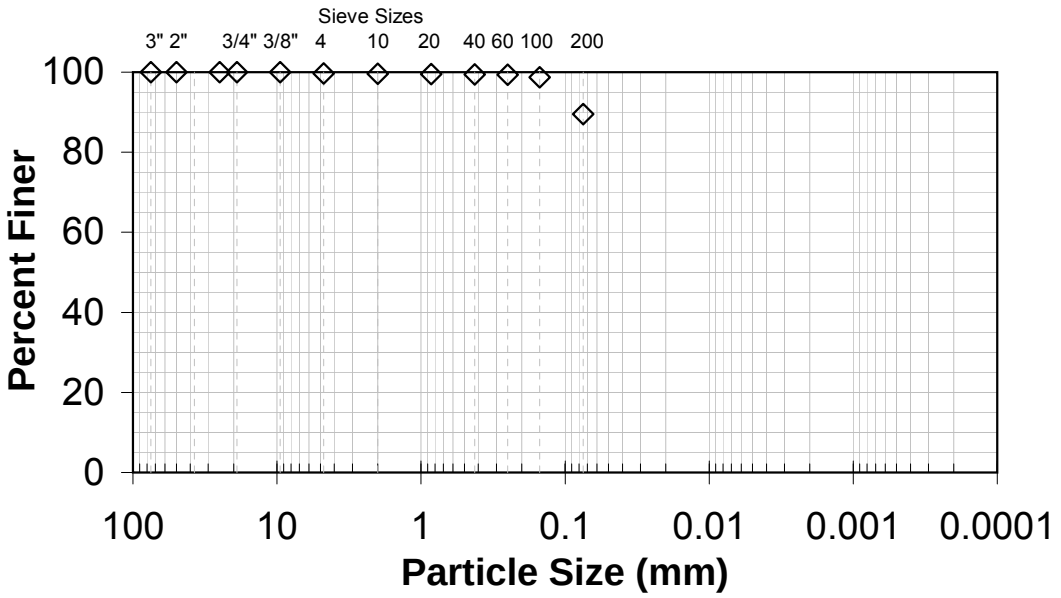
Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-6, 2'-4.5'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/21/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	99.7
No. 10 (2.00 mm)	99.6
No. 20 (850 μm)	99.5
No. 40 (425 μm)	99.4
No. 60 (250 μm)	99.3
No.100 (150 μm)	98.7
No. 200 (75 μm)	89.6

Notes: Soil classifies as a lean clay (CL) in accordance with ASTM D 2487. The as received moisture content was 20.3% as determined by ASTM D 2116.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	36
Plastic Limit	17
Plastic Index	19
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

Cheng-Wei Chen, 04/28/08
Review/Date

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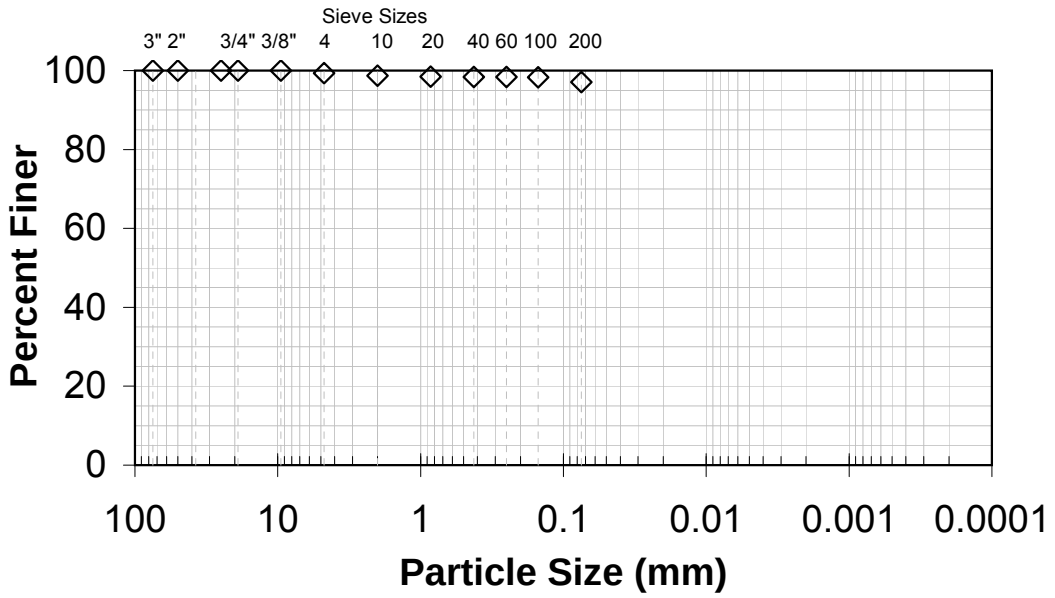
Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-6, 12.5'-15'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/28/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	99.4
No. 10 (2.00 mm)	98.7
No. 20 (850 μm)	98.5
No. 40 (425 μm)	98.4
No. 60 (250 μm)	98.4
No.100 (150 μm)	98.3
No. 200 (75 μm)	97.1

Notes: Soil classifies as a lean clay (CL) in accordance with ASTM D 2487. The as received moisture content was 26.1% as determined by ASTM D 2216.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	34
Plastic Limit	17
Plastic Index	17
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

Cheng-Wei Chen, 04/30/08
Review/Date

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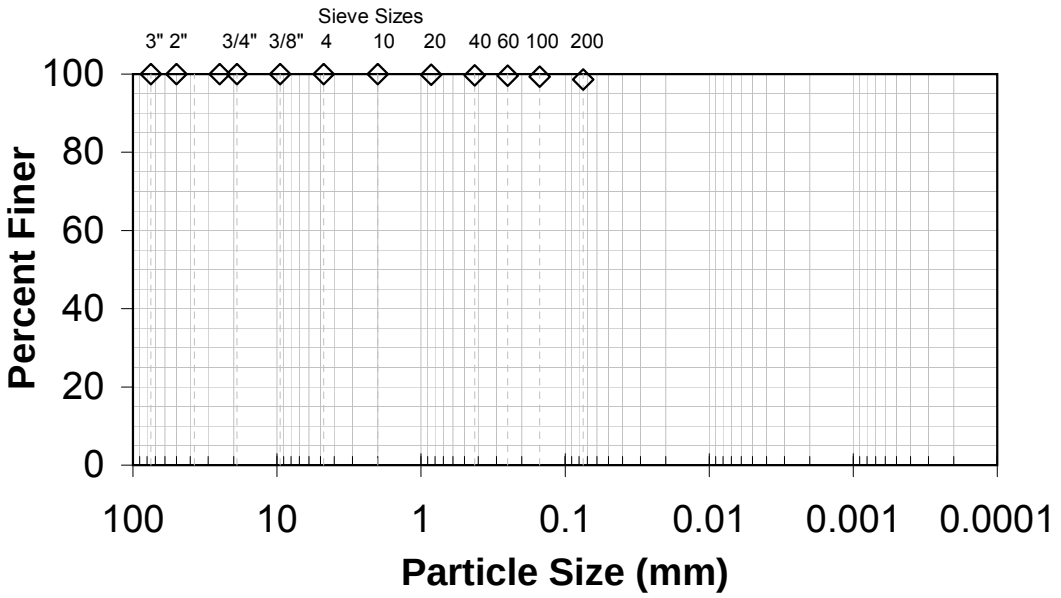
Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-6, 23'-25.5'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/21/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	100.0
No. 10 (2.00 mm)	100.0
No. 20 (850 μm)	99.8
No. 40 (425 μm)	99.7
No. 60 (250 μm)	99.6
No.100 (150 μm)	99.3
No. 200 (75 μm)	98.6

Notes: Soil classifies as a fat clay (CH) in accordance with ASTM D 2487. The as received moisture content was 27.8% as determined by ASTM D 2116.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	70
Plastic Limit	26
Plastic Index	44
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

Cheng-Wei Chen, 04/23/2008
Review/Date

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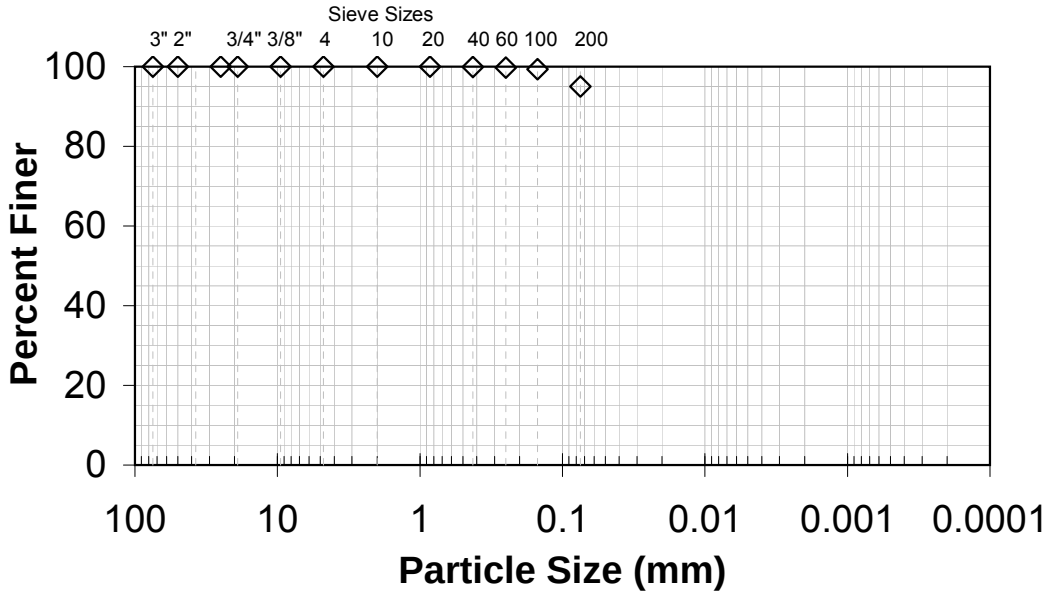
Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-6, 33'-35.5'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/22/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	100.0
No. 10 (2.00 mm)	100.0
No. 20 (850 μm)	100.0
No. 40 (425 μm)	99.9
No. 60 (250 μm)	99.7
No. 100 (150 μm)	99.3
No. 200 (75 μm)	95.1

Notes: Soil classifies as a fat clay (CH) in accordance with ASTM D 2487. The as received moisture content was 26.1% as determined by ASTM D 2116.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	56
Plastic Limit	20
Plastic Index	36
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

Cheng-Wei Chen, 04/23/2008
Review/Date

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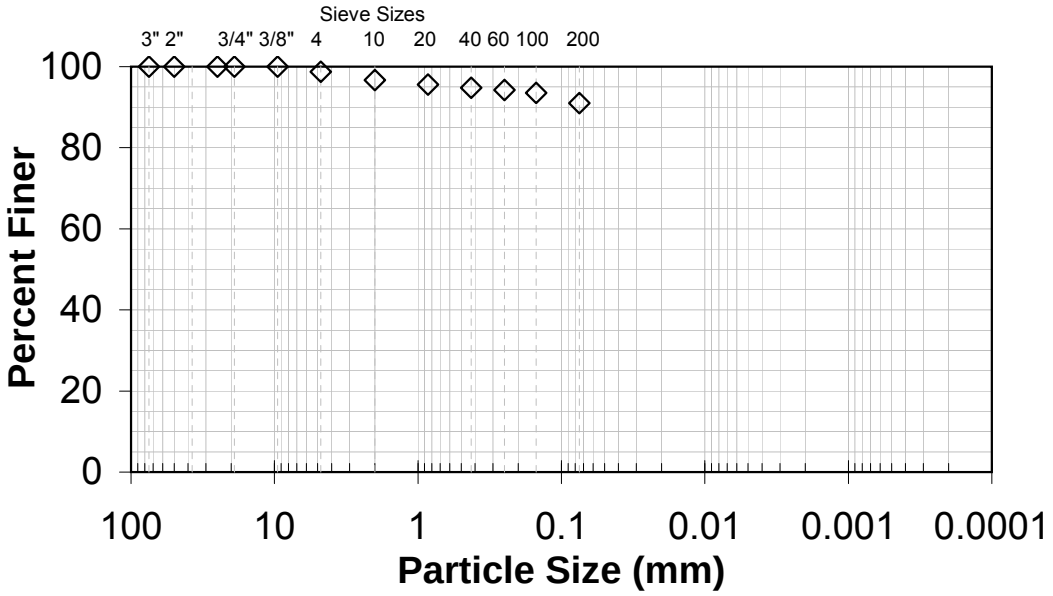
Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-6, 43.5'-46'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/24/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	98.7
No. 10 (2.00 mm)	96.7
No. 20 (850 μm)	95.6
No. 40 (425 μm)	94.8
No. 60 (250 μm)	94.3
No. 100 (150 μm)	93.5
No. 200 (75 μm)	91.0

Notes: Soil classifies as a lean clay (CL) in accordance with ASTM D 2487. The as received moisture content was 29.2% as determined by ASTM D 2116.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	37
Plastic Limit	19
Plastic Index	18
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

Cheng-Wei Chen, 04/28/08
Review/Date

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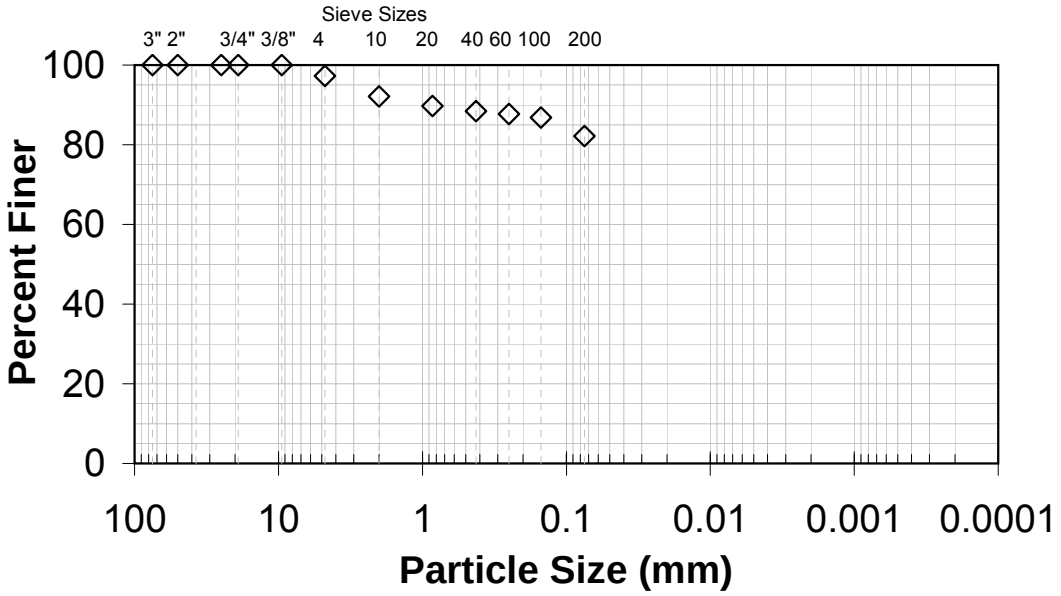
Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-7, 6'-8.5'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/16/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	97.3
No. 10 (2.00 mm)	92.1
No. 20 (850 μm)	89.7
No. 40 (425 μm)	88.4
No. 60 (250 μm)	87.7
No. 100 (150 μm)	86.9
No. 200 (75 μm)	82.2

Notes: Soil classifies as a lean clay with sand (CL) in accordance with ASTM D 2487. The as received moisture content was 21.6% as determined by ASTM D 2216.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	46
Plastic Limit	17
Plastic Index	29
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

Cheng-Wei Chen, 04/21/2008
Review/Date

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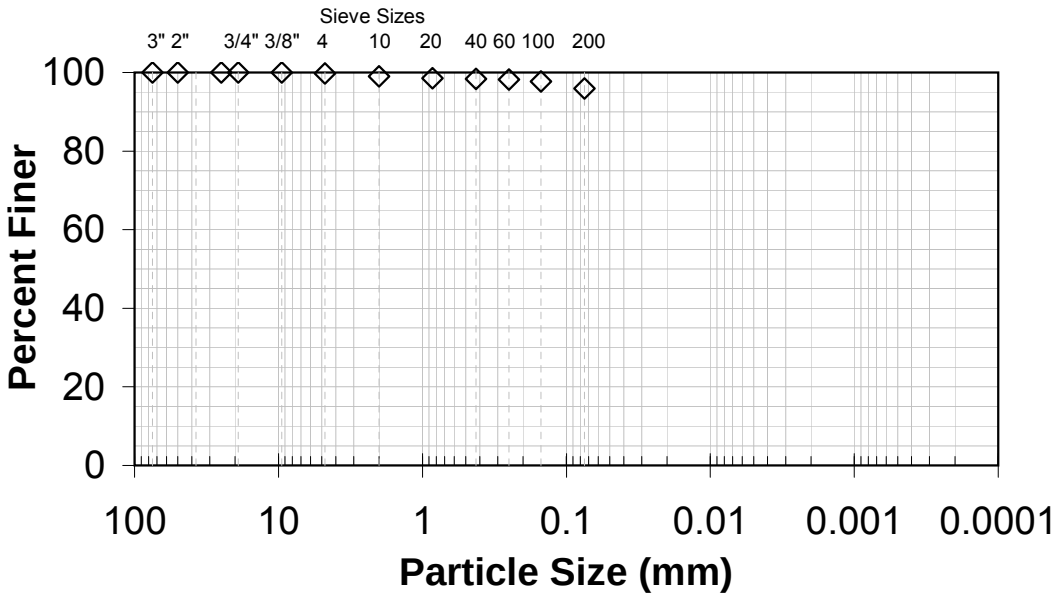
Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-7, 14.5'-18.5'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/11/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	99.7
No. 10 (2.00 mm)	99.0
No. 20 (850 μm)	98.6
No. 40 (425 μm)	98.4
No. 60 (250 μm)	98.2
No. 100 (150 μm)	97.7
No. 200 (75 μm)	95.9

Notes: Soil classifies as a fat clay (CH) in accordance with ASTM D 2487. The as received moisture content was 30.3% as determined by ASTM D 2216.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	80
Plastic Limit	30
Plastic Index	50
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

Cheng-Wei Chen, 04/16/2008
Review/Date

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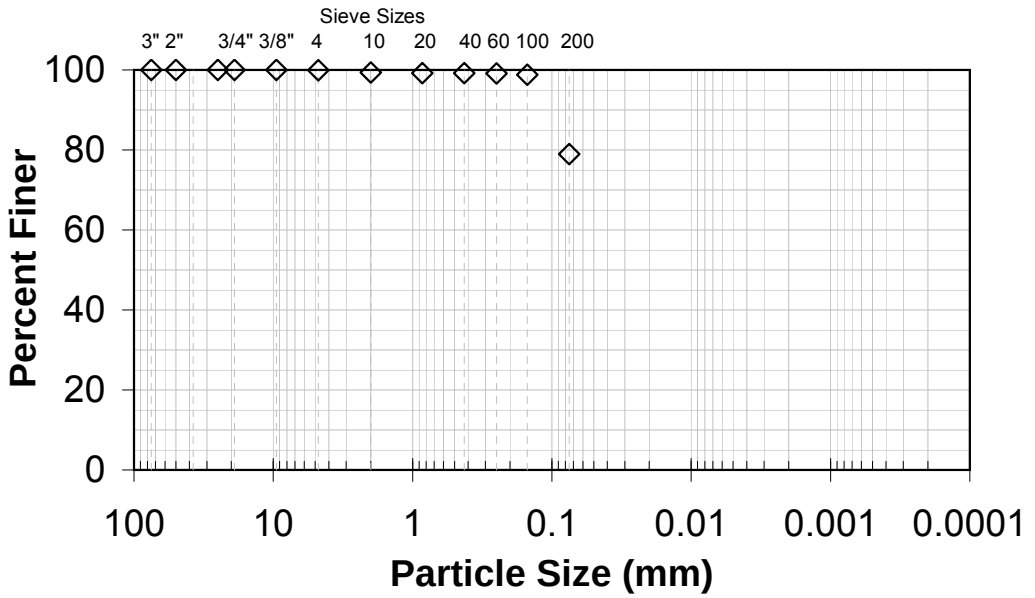
9063 Bee Caves Road □ Austin, TX 78733-6201 □ (512) 263-2101 □ (512) 263-2558 □ 1-800-880-TEST

Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-7, 26'-28.5'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/11/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	99.9
No. 10 (2.00 mm)	99.4
No. 20 (850 μm)	99.2
No. 40 (425 μm)	99.2
No. 60 (250 μm)	99.1
No. 100 (150 μm)	98.8
No. 200 (75 μm)	79.0

Notes: Soil classifies as a lean clay with sand (CL) in accordance with ASTM D 2487. The as received moisture content was 22.0% as determined by ASTM D 2216.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	27
Plastic Limit	17
Plastic Index	10
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

Cheng-Wei Chen, 04/16/2008
Review/Date

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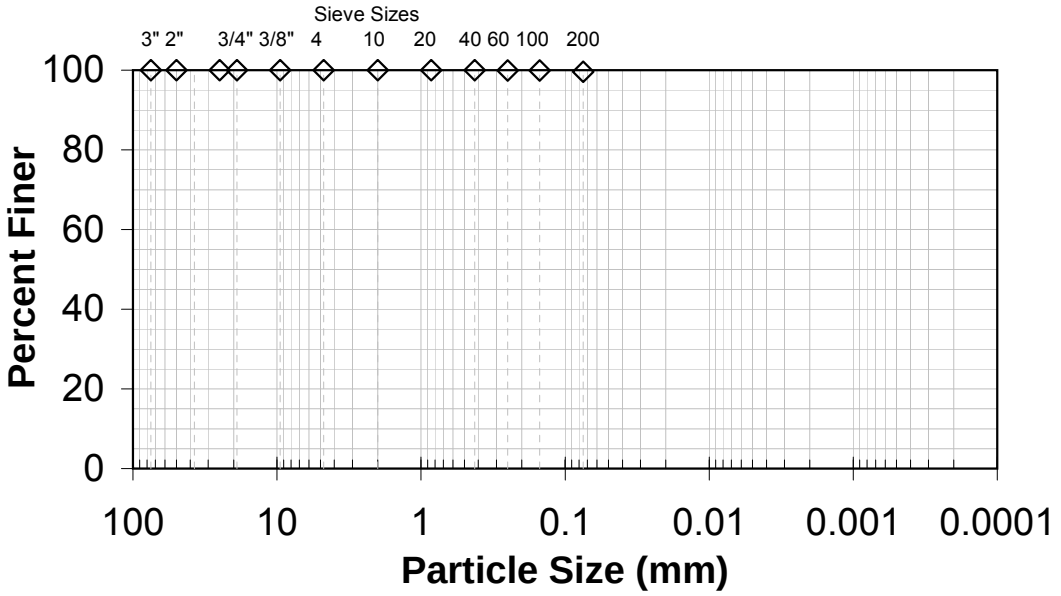
Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-7, 35.5'-38.5'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/11/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	100.0
No. 10 (2.00 mm)	100.0
No. 20 (850 μm)	100.0
No. 40 (425 μm)	100.0
No. 60 (250 μm)	99.9
No. 100 (150 μm)	99.9
No. 200 (75 μm)	99.6

Notes: Soil classifies as a fat clay (CH) in accordance with ASTM D 2487. The as received moisture content was 26.7% as determined by ASTM D 2216.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	69
Plastic Limit	24
Plastic Index	45
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

Cheng-Wei Chen, 04/16/2008
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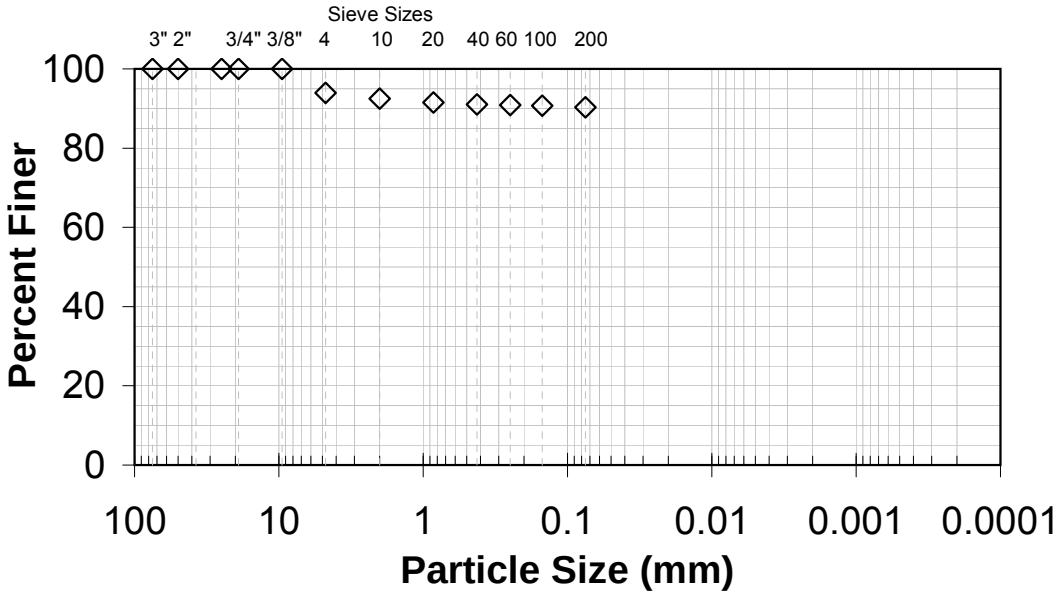
Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-7, 44.5'-47'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 04/23/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	94.0
No. 10 (2.00 mm)	92.5
No. 20 (850 μm)	91.5
No. 40 (425 μm)	91.1
No. 60 (250 μm)	90.8
No. 100 (150 μm)	90.7
No. 200 (75 μm)	90.3

Notes: Soil classifies as a lean clay (CL) in accordance with ASTM D 2487. The as received moisture content was 27.3% as determined by ASTM D 2216.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	32
Plastic Limit	22
Plastic Index	10
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

Cheng-Wei Chen, 04/28/08
Review/Date

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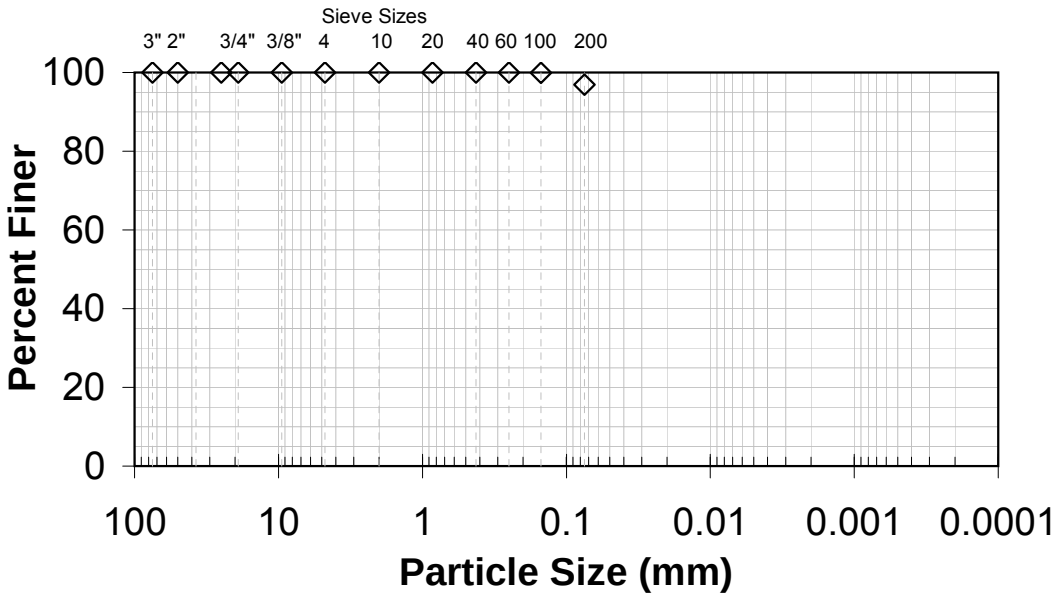
Particle Size Analysis for Soils

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-10, 9'-11.5'

TRI Log#: E2308-12-01
Test Method: ASTM D 422
Test Date: 05/06/08



Sieve Analysis	
Sieve Size	Percentage Passing (%)
3-in.	NA
2-in.	NA
1 in.	100.0
3/4 in.	100.0
3/8 in.	100.0
No. 4 (4.75 mm)	100.0
No. 10 (2.00 mm)	100.0
No. 20 (850 μm)	100.0
No. 40 (425 μm)	100.0
No. 60 (250 μm)	100.0
No. 100 (150 μm)	99.9
No. 200 (75 μm)	96.9

Notes: Soil classifies as a silt (ML) in accordance with ASTM D 2487. The as received moisture content was 22.2% as determined by ASTM D 2116.

Plastic Index (ASTM D 4318) Results	
Liquid Limit	NP
Plastic Limit	21
Plastic Index	NP
Notes: Specimen was air dried, 3 point Liquid Limit procedure was used.	

Cheng-Wei Chen, 5/08/08
Review/Date

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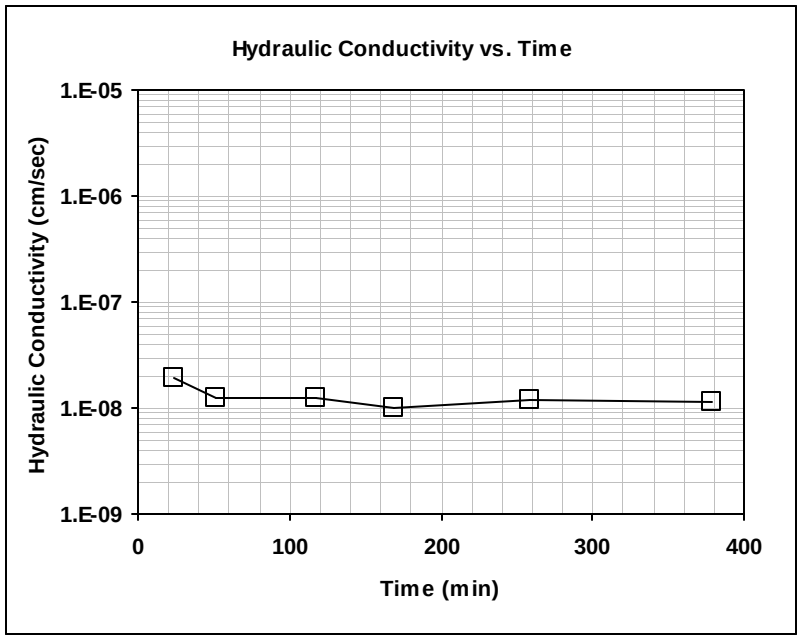
Hydraulic Conductivity

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-2, depth = 4'-6.5'

TRI Log#: E2308-12-01
Test Method: ASTM D 5084, Method F
Test Date: 04/21/08

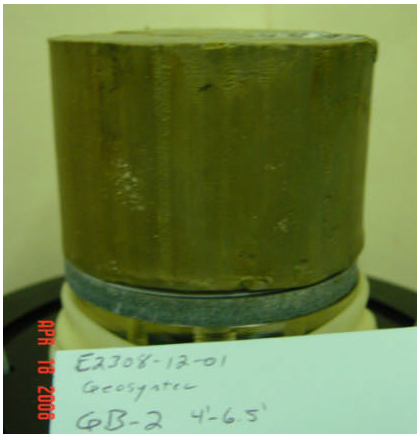


INITIAL VALUES	
Sample Height (in)	2.12
Sample Diameter (in)	2.82
Wet Weight (g)	449.4
Area (in^2)	6.25
Area (cm^2)	40.3
Sample Height (cm)	5.38
Volume (cc)	216.8
Initial Water Content (%)	19.7
Total Density (pcf)	129.4
Dry Density (pcf)	108.1
G_s (assumed)	2.65
Degree of Saturation	0.98
Void Ratio	0.529
Porosity	0.346
1 Pore Volume (cc)	75.0

Soil classifies as a lean clay (CL) in accordance with ASTM D 2488 (Visual-Manual Procedure). The as received moisture content was 19.7% as determined by ASTM D 2216.

Hydraulic Conductivity

Time (min)	k at 20 deg C (cm/sec)
24.0	1.89E-08
51.0	1.26E-08
117.0	1.23E-08
169.0	9.96E-09
259.0	1.19E-08
379.0	1.12E-08
Average[1]:	**1.1E-08**



Cheng-Wei Chen, 5/02/08
Quality Review/Date

1: Average corrected hydraulic conductivity (k_{20}) is obtained from the last 4 average readings.

Notes: A B-value of 0.95 was achieved. Permeation measurements were made with a mercury U-tube. The effective confining pressure was 5.6 psi (≈ 800 psf) based on the test request.

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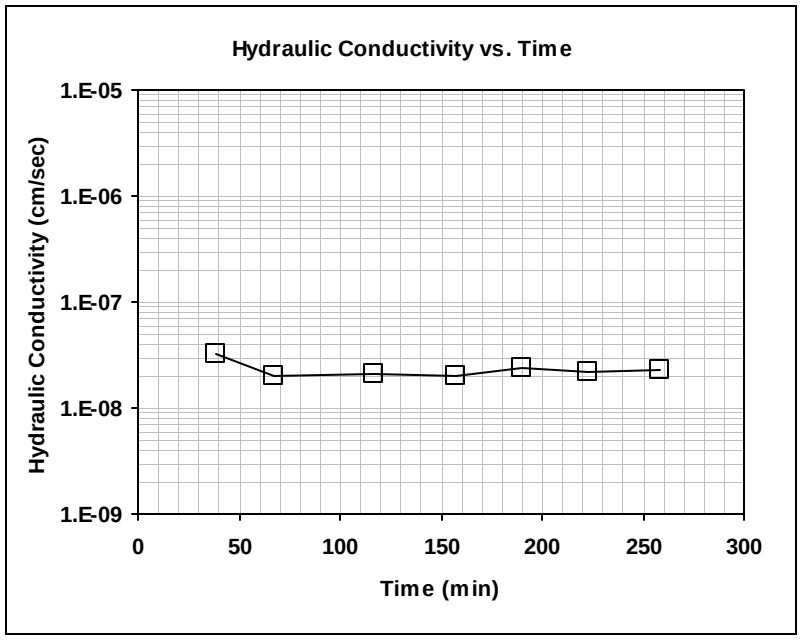
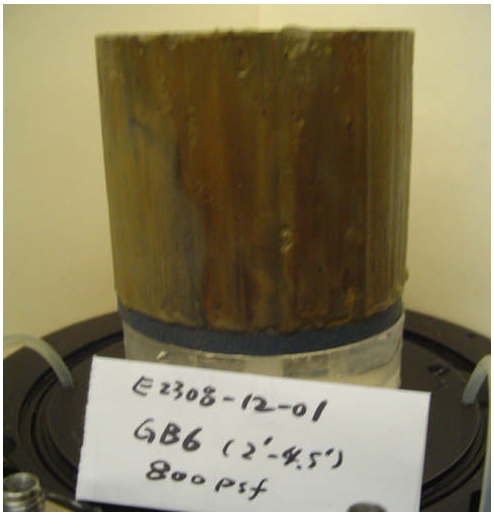
Hydraulic Conductivity

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-6, depth = 2'-4.5'

TRI Log#: E2308-12-01
Test Method: ASTM D 5084, Method F
Test Date: 05/06/08



INITIAL VALUES	
Sample Height (in)	2.51
Sample Diameter (in)	2.83
Wet Weight (g)	539.1
Area (in^2)	6.28
Area (cm^2)	40.5
Sample Height (cm)	6.38
Volume (cc)	258.4
Initial Water Content (%)	17.6
Total Density (pcf)	130.2
Dry Density (pcf)	110.7
G_s (assumed)	2.65
Degree of Saturation (%)	94.6
Void Ratio	0.494
Porosity	0.330
1 Pore Volume (cc)	85.4



Hydraulic Conductivity

Time (min)	k at 20 deg C (cm/sec)
39.0	3.17E-08
67.0	2.04E-08
117.0	2.11E-08
157.0	2.03E-08
190.0	2.35E-08
223.0	2.15E-08
258.0	2.29E-08
Average[1]:	**2.2E-08**

1: Average corrected hydraulic conductivity (k_{20}) is obtained from the last 4 average readings.

Notes: A B-value of 0.96 was achieved. Permeation measurements were made with a mercury U-tube. The effective confining pressure was 5.6 psi (≈ 800 psf) based on the test request.

Cheng-Wei Chen, 5/08/08
Quality Review/Date

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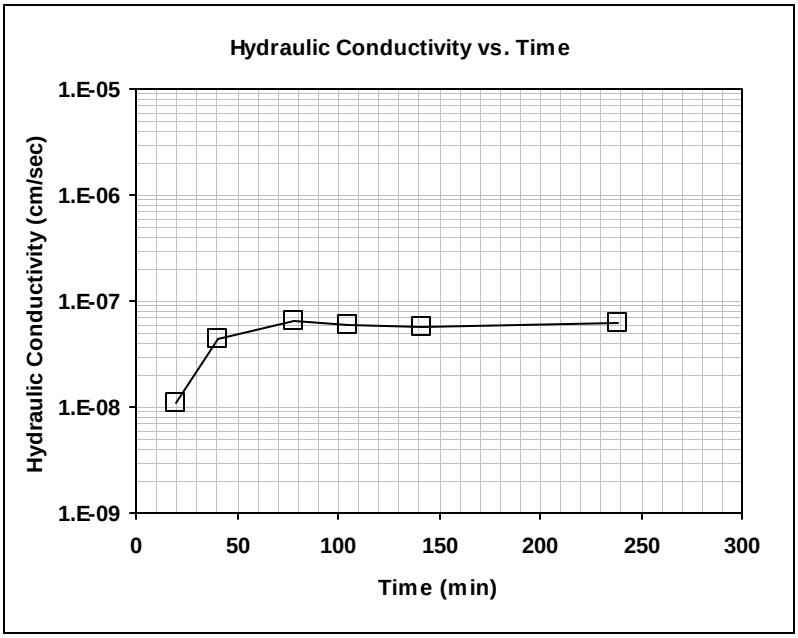
Hydraulic Conductivity

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-4, depth = 6'-8.5'

TRI Log#: E2308-12-01
Test Method: ASTM D 5084, Method F
Test Date: 04/28/08



INITIAL VALUES	
Sample Height (in)	1.86
Sample Diameter (in)	2.82
Wet Weight (g)	398.7
Area (in^2)	6.25
Area (cm^2)	40.3
Sample Height (cm)	4.73
Volume (cc)	190.4
Initial Water Content (%)	19.4
Total Density (pcf)	130.7
Dry Density (pcf)	109.4
G_s (assumed)	2.65
Degree of Saturation (%)	100
Void Ratio	0.511
Porosity	0.338
1 Pore Volume (cc)	64.4

Soil classifies as a lean clay (CL) in accordance with ASTM D 2488 (Visual-Manual Procedure). The as received moisture content was 19.4% as determined by ASTM D 2216.

Hydraulic Conductivity

Time (min)	k at 20 deg C (cm/sec)
20.0	1.08E-08
41.0	4.41E-08
78.0	6.45E-08
105.0	5.86E-08
142.0	5.57E-08
239.0	6.21E-08
Average[1]:	**6.0E-08**

1: Average corrected hydraulic conductivity (k_{20}) is obtained from the last 4 average readings.

Notes: A B-value of 0.97 was achieved. Permeation measurements were made with a mercury U-tube. The effective confining pressure was 5.6 psi (≈ 800 psf) based on the test request.

Cheng-Wei Chen, 5/02/08
Quality Review/Date

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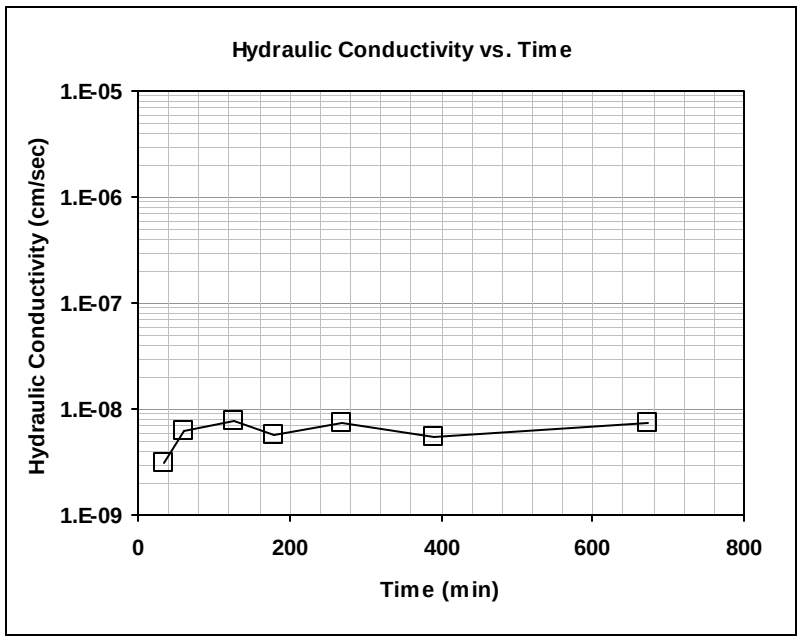
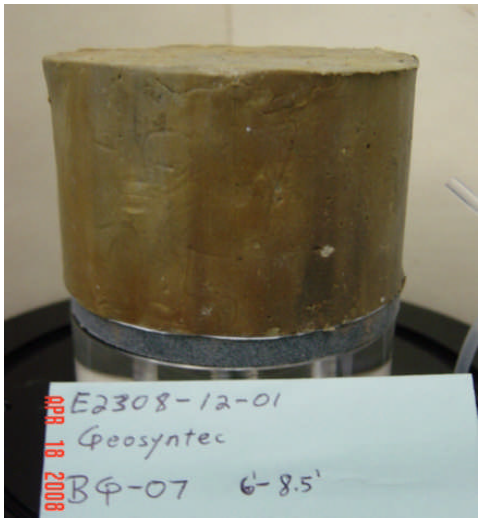
Hydraulic Conductivity

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-7, depth = 6'-8.5'

TRI Log#: E2308-12-01
Test Method: ASTM D 5084, Method F
Test Date: 04/21/08



INITIAL VALUES	
Sample Height (in)	1.93
Sample Diameter (in)	2.83
Wet Weight (g)	416.4
Area (in^2)	6.28
Area (cm^2)	40.5
Sample Height (cm)	4.90
Volume (cc)	198.6
Initial Water Content (%)	21.5
Total Density (pcf)	130.9
Dry Density (pcf)	107.7
G_s (assumed)	2.65
Degree of Saturation	100.0
Void Ratio	0.535
Porosity	0.349
1 Pore Volume (cc)	69.2



Hydraulic Conductivity

Time (min)	k at 20 deg C (cm/sec)
35.0	3.08E-09
62.0	6.24E-09
128.0	7.75E-09
180.0	5.74E-09
270.0	7.32E-09
390.0	5.45E-09
673.0	7.45E-09
Average[1]:	**6.5E-09**

1: Average corrected hydraulic conductivity (k_{20}) is obtained from the last 4 average readings.

Notes: A B-value of 0.97 was achieved. Permeation measurements were made with a mercury U-tube. The effective confining pressure was 5.6 psi (≈ 800 psf) based on the test request.

Cheng-Wei Chen, 4/24/08
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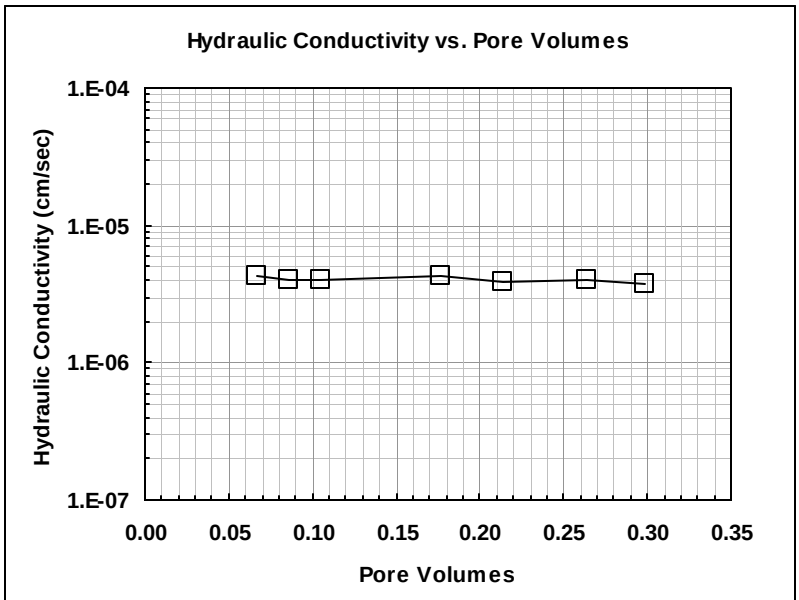
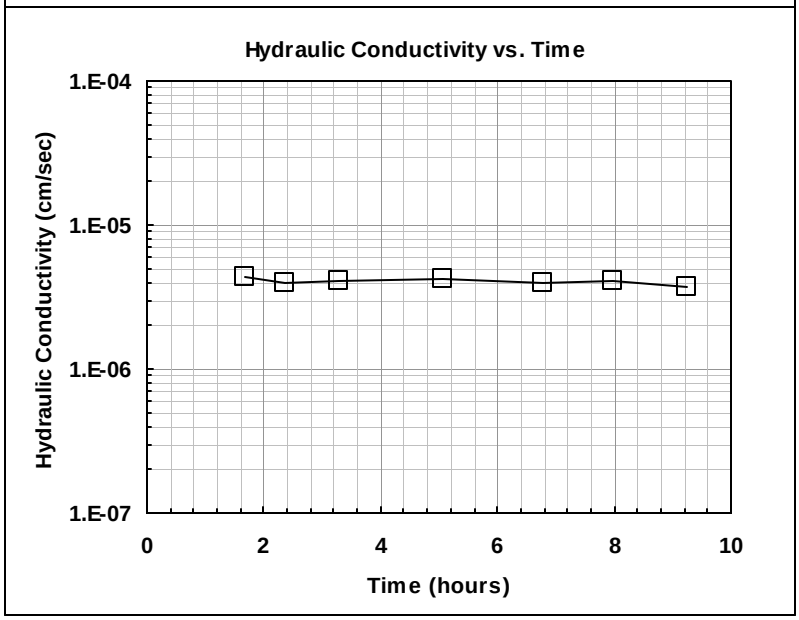
Hydraulic Conductivity

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-10, 9'-11.5'

TRI Log#: E2308-12-01
Test Method: ASTM D 5084
Test Date: 05/01/08





INITIAL VALUES	
Sample height (in)	1.55
Sample Diameter (in)	2.71
Wet Weight (g)	268.5
Sample Area (in^2)	5.76
Sample Area (cm^2)	37.18
Sanple height (cm)	3.94
Sample Volume (cc)	146.7
Moisture content (%)	22.19
Wet Density (pcf)	114.3
Dry Density (pcf)	93.5
G_s (assumed)	2.65
Degree of Saturation	100
Void Ratio	0.769
Porosity	0.435
1 Pore Volume (cc)	63.7
Effective Consolidation Stress (psi)	8.3

	Hydraulic Conductivity	
Time (hrs)	k (cm/sec)	k at 20 deg C (cm/sec)
1.7	4.4E-06	4.3E-06
2.4	4.1E-06	4.0E-06
3.3	4.1E-06	4.0E-06
5.1	4.3E-06	4.2E-06
6.8	4.0E-06	3.9E-06
8.0	4.2E-06	4.1E-06
9.3	3.9E-06	3.8E-06
Avg. K[1] at 20 deg C:		**4.0E-06**

1: Average corrected hydraulic conductivity (k_{20}) is obtained from the last 4 average readings.

Cheng-Wei Chen, 5/05/08
Quality Review/Date

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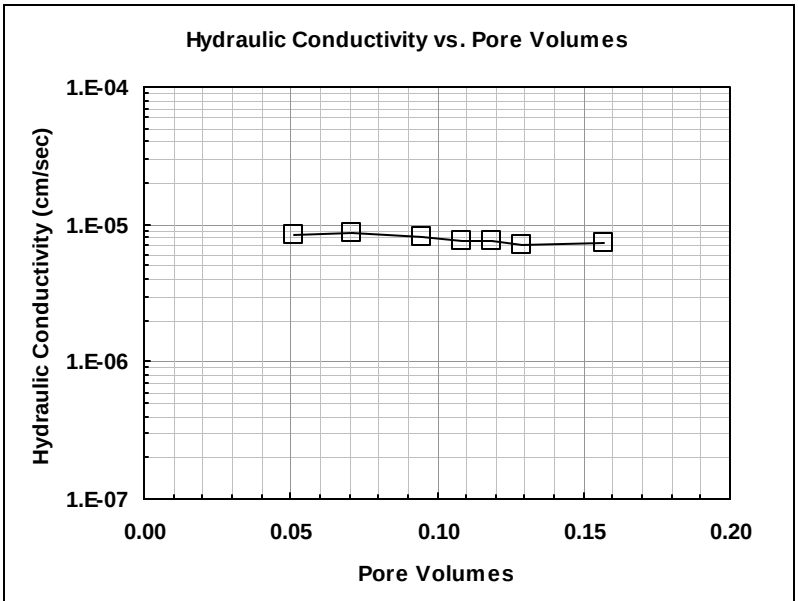
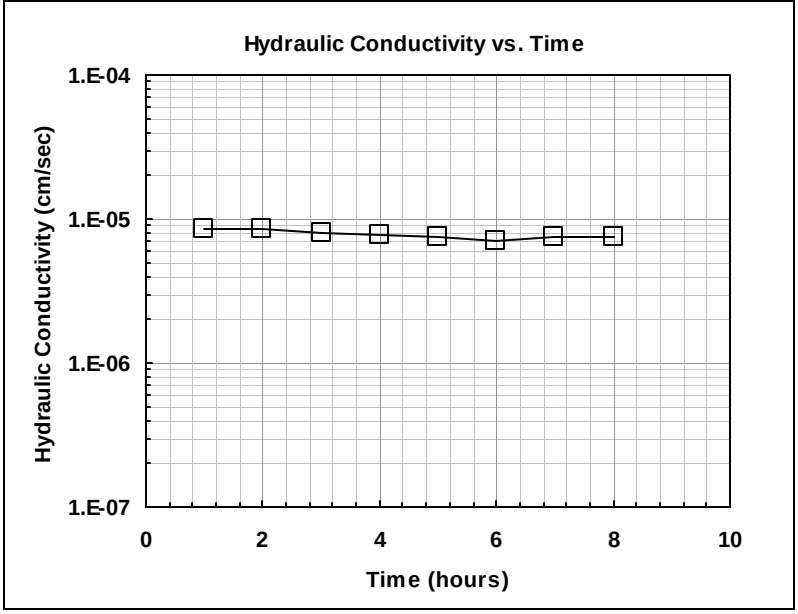
Hydraulic Conductivity

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-3, 10.5'-13.0' (soft silt)

TRI Log#: E2308-12-01
Test Method: ASTM D 5084, Method C
Test Date: 04/21/08





INITIAL VALUES	
Sample height (in)	2.73
Sample Diameter (in)	2.81
Wet Weight (g)	573.0
Sample Area (in^2)	6.19
Sample Area (cm^2)	39.92
Sanple height (cm)	6.93
Sample Volume (cc)	276.8
Moisture content (%)	27.2
Wet Density (pcf)	129.2
Dry Density (pcf)	101.6
G_s (assumed)	2.65
Degree of Saturation	100.0
Void Ratio	0.628
Porosity	0.386
1 Pore Volume (cc)	106.8
Effective Consolidation Stress (psi)	5.6

	Hydraulic Conductivity	
Time (hrs)	k (cm/sec)	k at 20 deg C (cm/sec)
2.0	8.6E-06	8.4E-06
2.5	8.8E-06	8.6E-06
3.5	8.3E-06	8.1E-06
4.3	7.8E-06	7.6E-06
5.1	7.7E-06	7.6E-06
6.2	7.2E-06	7.0E-06
7.2	7.6E-06	7.4E-06
Avg. K^1 at 20 deg C:		**7.4E-06**

1: Average corrected hydraulic conductivity (k_{20}) is obtained from the last 4 average readings.

Cheng-Wei Chen, 4/22/08
Quality Review/Date

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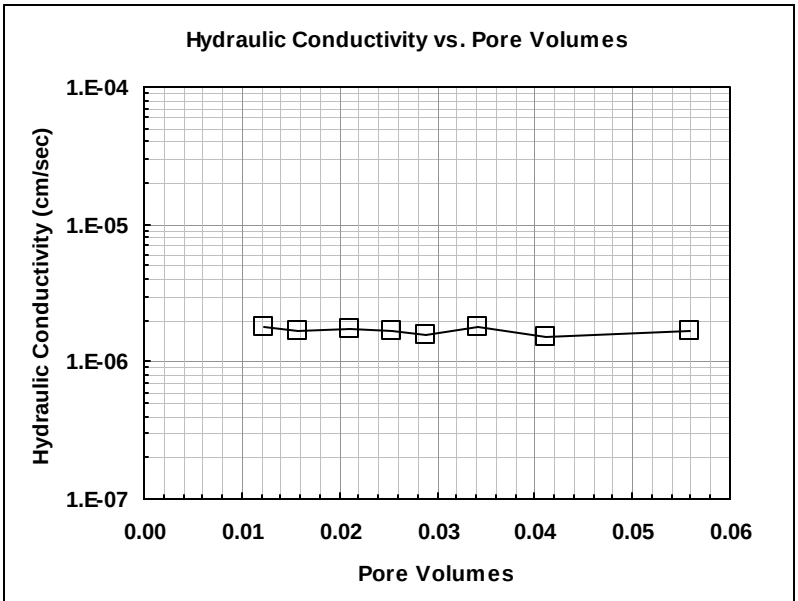
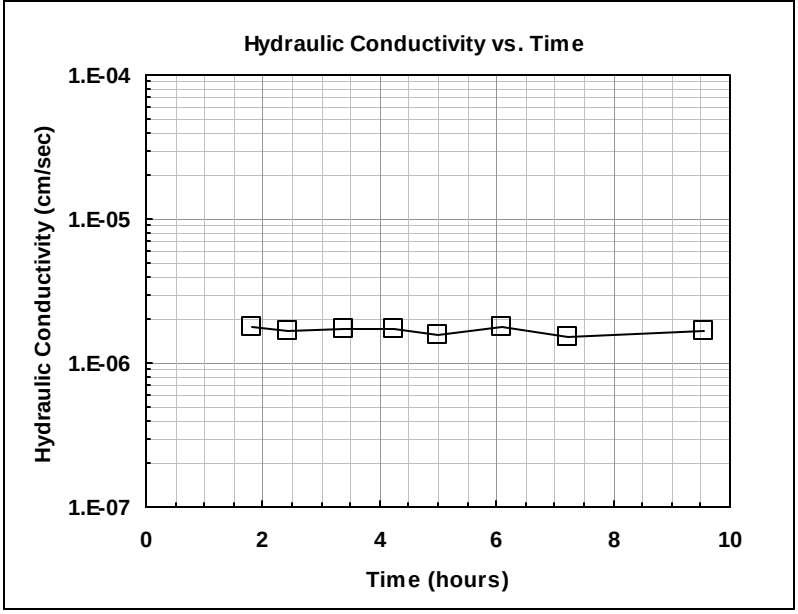
Hydraulic Conductivity

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-3, 10.5'-13.0' (stiff clay)

TRI Log#: E2308-12-01
Test Method: ASTM D 5084
Test Date: 04/21/08





INITIAL VALUES	
Sample height (in)	2.77
Sample Diameter (in)	2.80
Wet Weight (g)	552.7
Sample Area (in^2)	6.14
Sample Area (cm^2)	39.61
Sanple height (cm)	7.03
Sample Volume (cc)	278.5
Moisture content (%)	27.03
Wet Density (pcf)	123.9
Dry Density (pcf)	97.5
G_s (assumed)	2.65
Degree of Saturation	100
Void Ratio	0.696
Porosity	0.410
1 Pore Volume (cc)	114.3
Effective Consolidation Stress (psi)	5.6

	Hydraulic Conductivity	
Time (hrs)	k (cm/sec)	k at 20 deg C (cm/sec)
1.8	1.8E-06	1.8E-06
2.4	1.7E-06	1.7E-06
3.4	1.8E-06	1.7E-06
4.2	1.7E-06	1.7E-06
5.0	1.6E-06	1.6E-06
6.1	1.8E-06	1.8E-06
7.2	1.5E-06	1.5E-06
9.6	1.7E-06	1.7E-06
Avg. K[1] at 20 deg C:		**1.6E-06**

1: Average corrected hydraulic conductivity (k_{20}) is obtained from the last 4 average readings.

Cheng-Wei Chen, 4/24/08
Quality Review/Date

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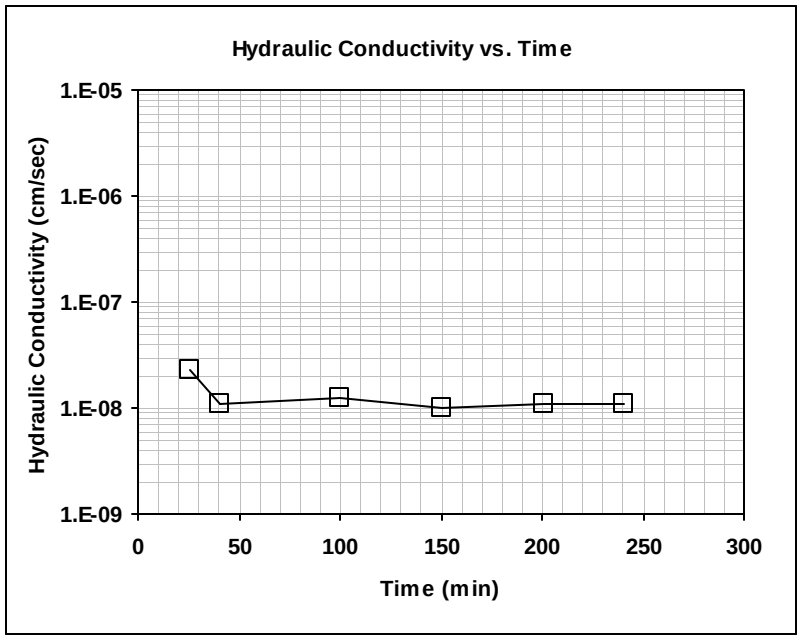
Hydraulic Conductivity

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-3, depth = 14'-16.5'

TRI Log#: E2308-12-01
Test Method: ASTM D 5084, Method F
Test Date: 05/01/08

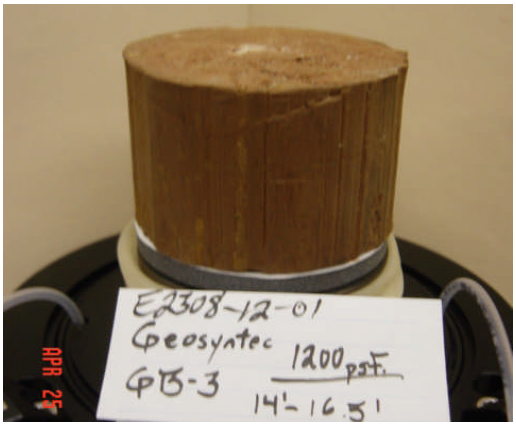


INITIAL VALUES	
Sample Height (in)	2.04
Sample Diameter (in)	2.80
Wet Weight (g)	400.3
Area (in^2)	6.15
Area (cm^2)	39.7
Sample Height (cm)	5.17
Volume (cc)	205.3
Initial Water Content (%)	28.4
Total Density (pcf)	121.7
Dry Density (pcf)	94.8
G_s (assumed)	2.65
Degree of Saturation (%)	100
Void Ratio	0.744
Porosity	0.427
1 Pore Volume (cc)	87.6

Soil classifies as a fat clay (CH) in accordance with ASTM D 2488 (Visual-Manual Procedure). The as received moisture content was 28.4% as determined by ASTM D 2216.

Hydraulic Conductivity

Time (min)	k at 20 deg C (cm/sec)
26.0	2.27E-08
41.0	1.08E-08
100.0	1.25E-08
150.0	9.95E-09
201.0	1.08E-08
241.0	1.10E-08
Average[1]:	**1.1E-08**



1: Average corrected hydraulic conductivity (k_{20}) is obtained from the last 4 average readings.

Notes: A B-value of 0.96 was achieved. Permeation measurements were made with a mercury U-tube. The effective confining pressure was 8.3 psi (≈ 1200 psf) based on the test request.

Cheng-Wei Chen, 5/2/08
Quality Review/Date

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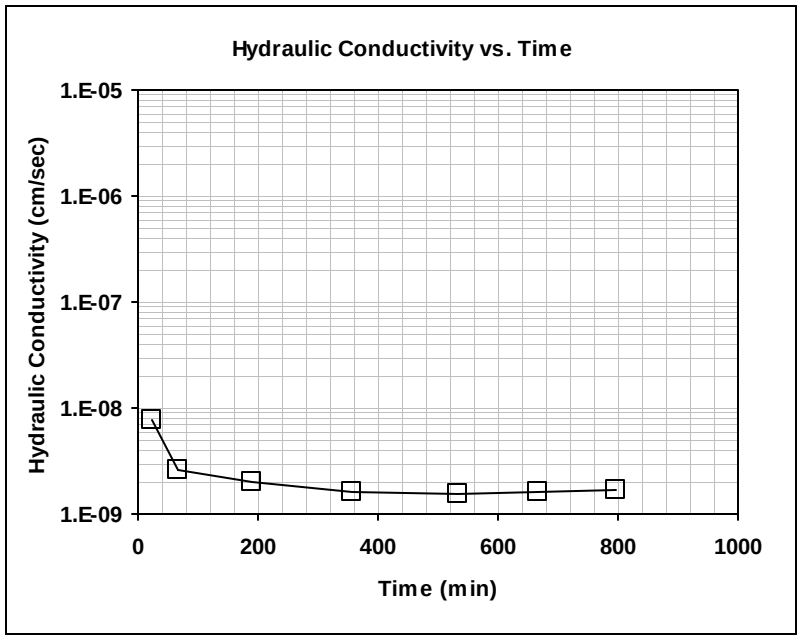
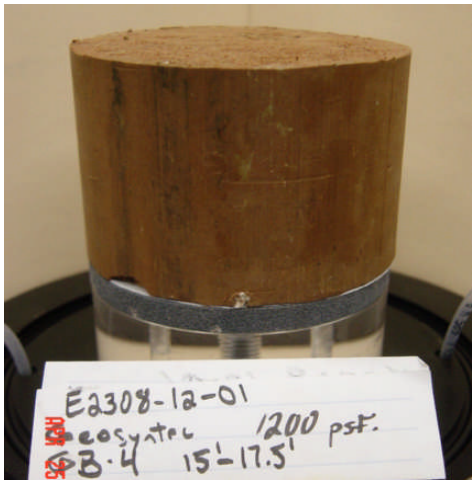
Hydraulic Conductivity

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-4, depth = 15'-17.5'

TRI Log#: E2308-12-01
Test Method: ASTM D 5084, Method F
Test Date: 05/02/08



INITIAL VALUES	
Sample Height (in)	2.01
Sample Diameter (in)	2.82
Wet Weight (g)	394.4
Area (in^2)	6.24
Area (cm^2)	40.2
Sample Height (cm)	5.10
Volume (cc)	205.2
Initial Water Content (%)	28.1
Total Density (pcf)	120.0
Dry Density (pcf)	93.7
G_s (assumed)	2.65
Degree of Saturation (%)	97
Void Ratio	0.765
Porosity	0.434
1 Pore Volume (cc)	88.9



Hydraulic Conductivity

Time (min)	k at 20 deg C (cm/sec)
22.0	7.82E-09
66.0	2.65E-09
190.0	2.00E-09
355.0	1.58E-09
534.0	1.53E-09
665.0	1.63E-09
795.0	1.71E-09
Average[1]:	**1.6E-09**

1: Average corrected hydraulic conductivity (k_{20}) is obtained from the last 4 average readings.

Notes: A B-value of 0.96 was achieved. Permeation measurements were made with a mercury U-tube. The effective confining pressure was 8.3 psi (≈ 1200 psf) based on the test request.

Cheng-Wei Chen, 5/05/08
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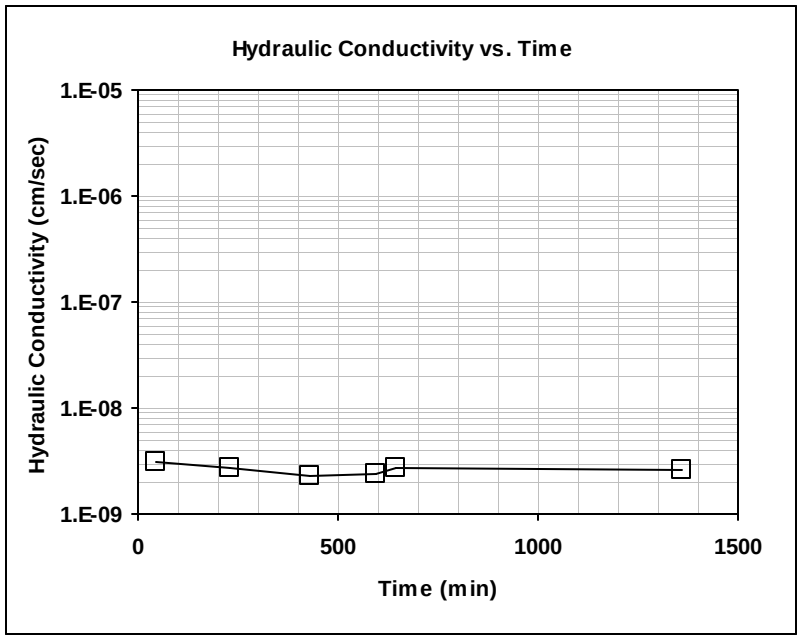
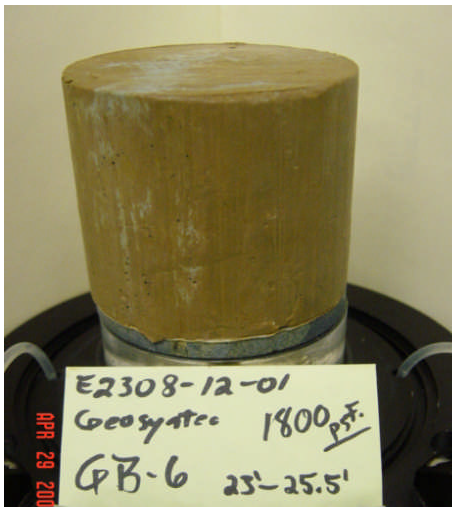
Hydraulic Conductivity

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-6, depth = 23'-25.5'

TRI Log#: E2308-12-01
Test Method: ASTM D 5084, Method F
Test Date: 04/28/08



INITIAL VALUES	
Sample Height (in)	2.52
Sample Diameter (in)	2.83
Wet Weight (g)	505.7
Area (in^2)	6.29
Area (cm^2)	40.6
Sample Height (cm)	6.40
Volume (cc)	260.0
Initial Water Content (%)	28.8
Total Density (pcf)	121.4
Dry Density (pcf)	94.2
G_s (assumed)	2.65
Degree of Saturation (%)	100
Void Ratio	0.755
Porosity	0.430
1 Pore Volume (cc)	111.9



Hydraulic Conductivity

Time (min)	k at 20 deg C (cm/sec)
45.0	3.12E-09
230.0	2.73E-09
430.0	2.28E-09
596.0	2.37E-09
644.0	2.73E-09
1361.0	2.64E-09
Average[1]:	**2.5E-09**

1: Average corrected hydraulic conductivity (k_{20}) is obtained from the last 4 average readings.

Notes: A B-value of 0.98 was achieved. Permeation measurements were made with a mercury U-tube. The effective confining pressure was 12.5 psi (≈ 1800 psf) based on the test request.

Cheng-Wei Chen, 4/29/08
Quality Review/Date

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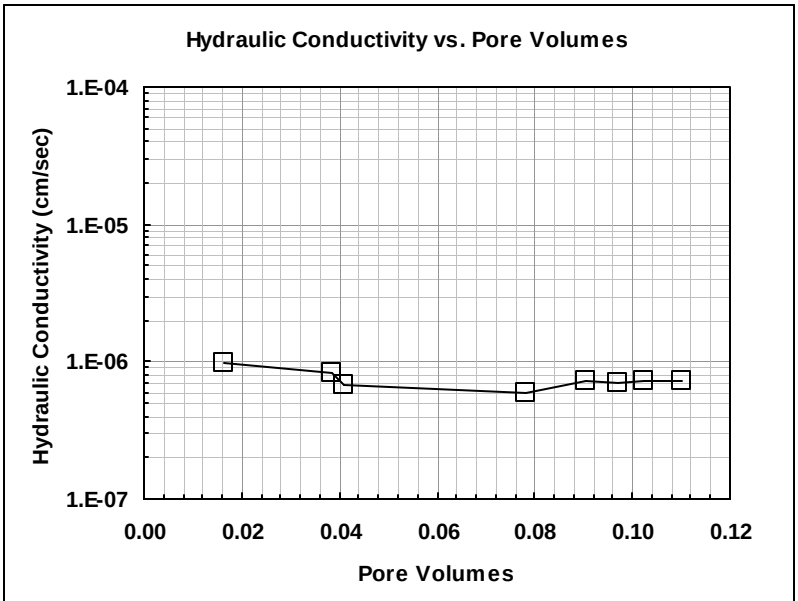
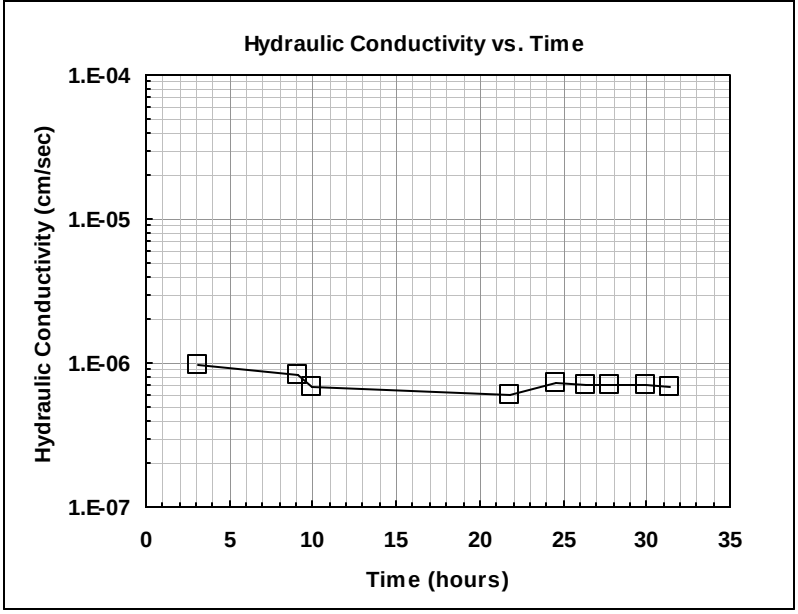
Hydraulic Conductivity

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
Sample: GB-6, 43.5'-46'

TRI Log#: E2308-12-01
Test Method: ASTM D 5084
Test Date: 04/21/08





INITIAL VALUES	
Sample height (in)	2.19
Sample Diameter (in)	2.80
Wet Weight (g)	443.2
Sample Area (in^2)	6.15
Sample Area (cm^2)	39.68
Sanple height (cm)	5.57
Sample Volume (cc)	221.0
Moisture content (%)	28.41
Wet Density (pcf)	125.2
Dry Density (pcf)	97.5
G_s (assumed)	2.65
Degree of Saturation	100
Void Ratio	0.697
Porosity	0.411
1 Pore Volume (cc)	90.7
Effective Consolidation Stress (psi)	20.8

	Hydraulic Conductivity	
Time (hrs)	k (cm/sec)	k at 20 deg C (cm/sec)
3.1	9.9E-07	9.7E-07
9.2	8.4E-07	8.2E-07
10.0	6.9E-07	6.7E-07
21.8	6.1E-07	5.9E-07
24.6	7.5E-07	7.3E-07
26.4	7.2E-07	7.0E-07
27.8	7.3E-07	7.1E-07
30.0	7.3E-07	7.1E-07
31.4	7.1E-07	6.9E-07
Avg. K^1 at 20 deg C:		**7.0E-07**

1: Average corrected hydraulic conductivity (k_{20}) is obtained from the last 4 average readings.

Cheng-Wei Chen, 5/01/08
Quality Review/Date

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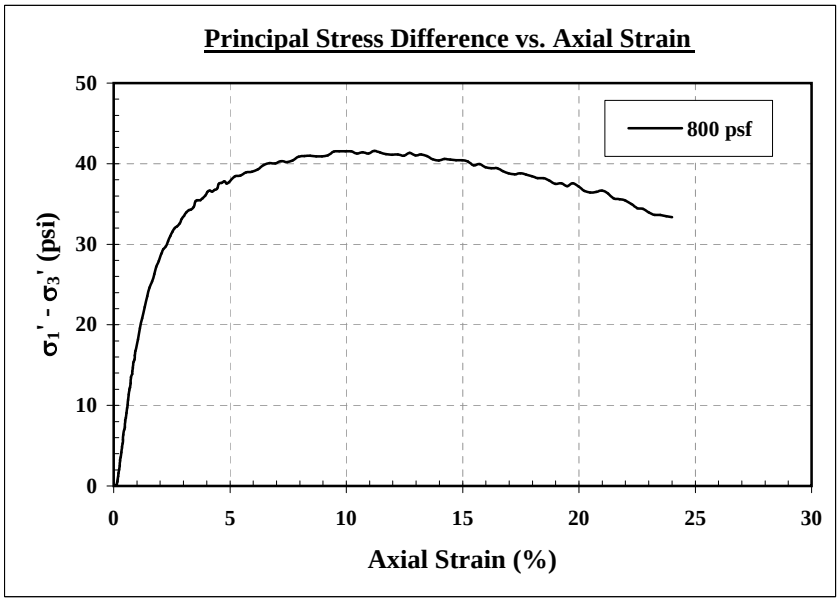
Unconsolidated-Undrained Triaxial Compression Test Report

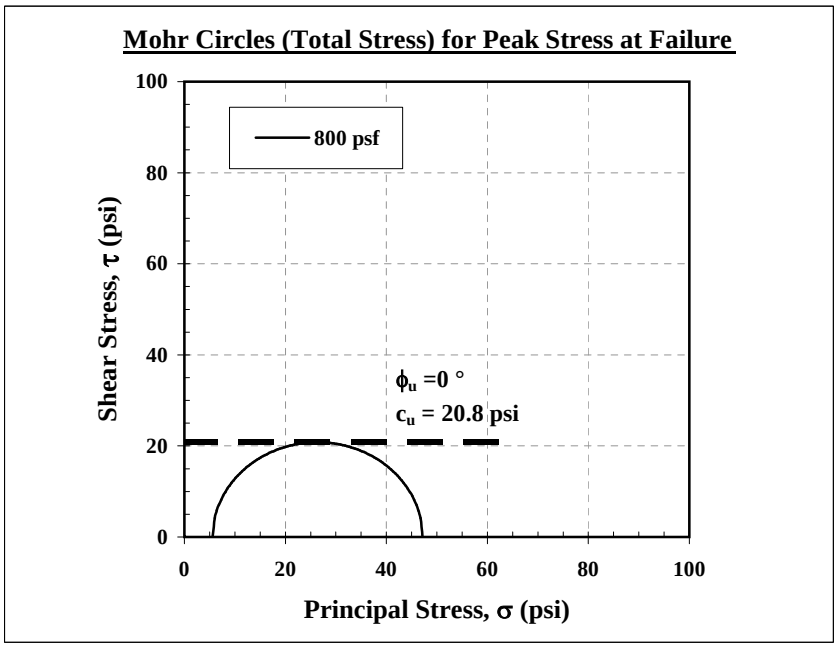
Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
TRI Log No.: E2308-12-01
Test Method: ASTM D 2850
Test Date: 4/22/2008
Sample Description: CL

Boring No.: GB2, 6.5'-9'
Sample No: - -
Type of Specimen: Undisturbed
Type of Test: Q-Test
Strain Rate (%/min): 1 % / min

Test Results	
Total Stresses (at Max. Deviator Stress)	
Friction Angle, ϕ_u (^{o}):	**0**
Cohesion, c_u (psi):	**20.8**



Initial Specimen Conditions		
Specimen No.		1
Confining Stress (psf)		800
Depth/Elev (ft):		6.5'-9'
Diameter (in)	D_o	2.83
Height (in)	H_o	5.62
Water Content (%)	w_o	17.7
Bulk Density (pcf)	γ_{total}	131.2
Dry Density (pcf)	γ_{dry}	111.5
Saturation (%)	S_o	96.9
Void Ratio	e_o	0.48
Assumed Specific Gravity	G_s	2.65



Peak Stresses at Failure	
Maximum Deviator Stress (psi)	41.6
Axial Strain at Failure (%)	11.2
Total Stresses at Failure (Peak Stress)	
σ_1 (psi)	47.2
σ_3 (psi)	5.6

Cheng-Wei Chen, 04/28/08
Quality Review/Date

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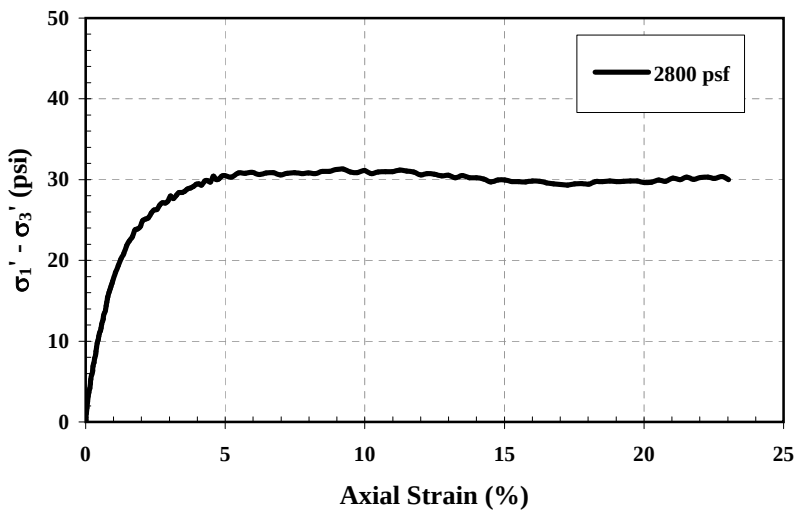
Unconsolidated-Undrained Triaxial Compression Test Report

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
TRI Log No.: E2308-12-01
Test Method: ASTM D 2850
Test Date: 4/22/2008
Sample Description: CL

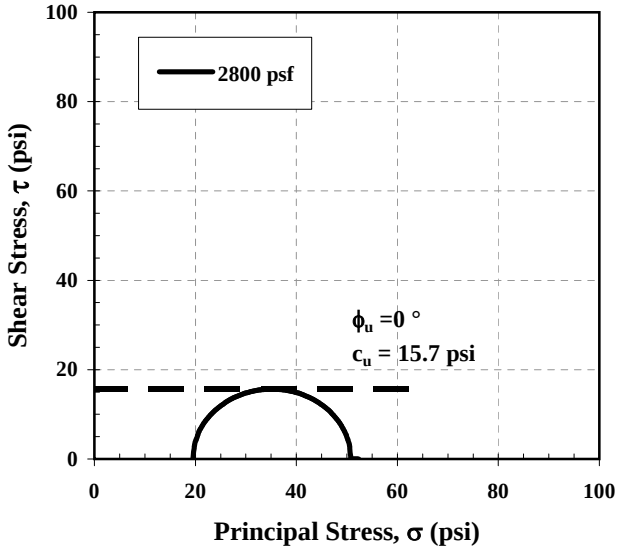
Boring No.: GB4, 6'-8.5'
Sample No: - -
Type of Specimen: Undisturbed
Type of Test: Q-Test
Strain Rate (%/min): 1 % / min

Test Results	
Total Stresses (at Max. Deviator Stress)	
Friction Angle, ϕ_u (^{o}):	**0**
Cohesion, c_u (psi):	**15.7**

Principal Stress Difference vs. Axial Strain



Mohr Circles (Total Stress) for Peak Stress at Failure



Initial Specimen Conditions		
Specimen No.		1
Confining Stress (psi)		19.5
Depth/Elev (ft):		6'-8.5'
Diameter (in)	D_o	2.83
Height (in)	H_o	5.70
Water Content (%)	w_o	16.6
Bulk Density (pcf)	γ_{total}	130.1
Dry Density (pcf)	γ_{dry}	111.6
Saturation (%)	S_o	91.1
Void Ratio	e_o	0.48
Assumed Specific Gravity	G_s	2.65

Peak Stresses at Failure	
Maximum Deviator Stress (psi)	31.3
Axial Strain at Failure (%)	9.2
Total Stresses at Failure (Peak Stress)	
σ_1 (psi)	50.8
σ_3 (psi)	19.5

Cheng-Wei Chen, 04/28/08
Quality Review/Date

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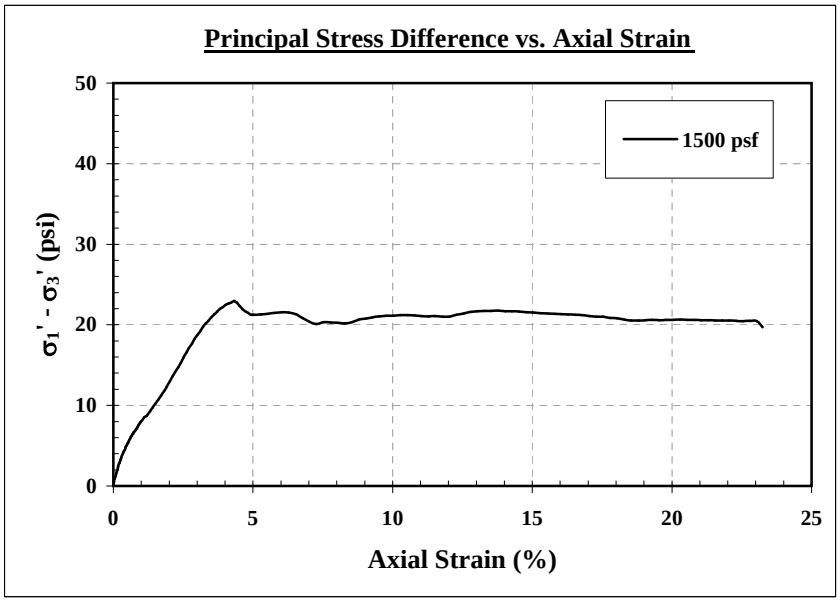
Unconsolidated-Undrained Triaxial Compression Test Report

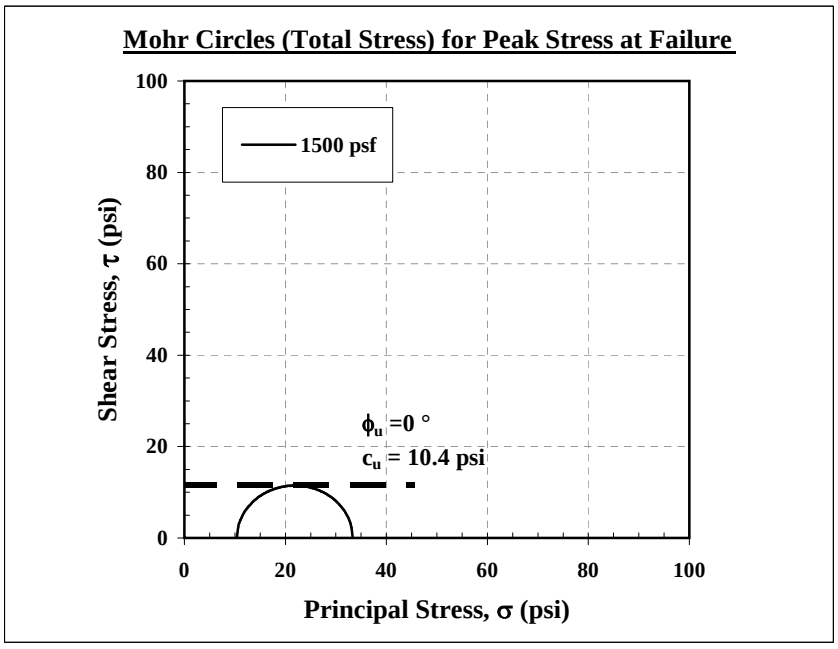
Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
TRI Log No.: E2308-12-01
Test Method: ASTM D 2850
Test Date: 4/19/2008
Sample Description: CH

Boring No.: GB2, 19'-21.5'
Sample No: - -
Type of Specimen: Undisturbed
Type of Test: Q-Test
Strain Rate (%/min): 1 % / min

Test Results	
Total Stresses (at Max. Deviator Stress)	
Friction Angle, ϕ_u (^{o}):	**0.0**
Cohesion, c_u (psi):	**11.5**



Initial Specimen Conditions		
Specimen No.		1
Confining Stress (psf)		1500
Depth/Elev (ft):		19-21.5
Diameter (in)	D_o	2.81
Height (in)	H_o	5.83
Water Content (%)	w_o	32.4
Bulk Density (pcf)	γ_{total}	125.2
Dry Density (pcf)	γ_{dry}	94.6
Saturation (%)	S_o	100.0
Void Ratio	e_o	0.75
Assumed Specific Gravity	G_s	2.65



Peak Stresses at Failure	
Maximum Deviator Stress (psi)	22.9
Axial Strain at Failure (%)	4.3
Total Stresses at Failure (Peak Stress)	
σ_1 (psi)	33.3
σ_3 (psi)	10.4

Cheng-Wei Chen 4/27/08
Quality Review/Date

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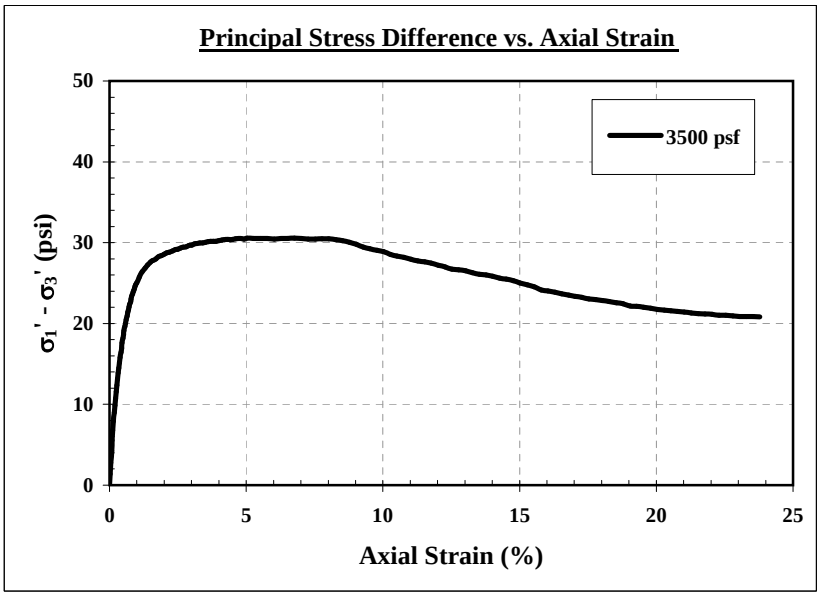
Unconsolidated-Undrained Triaxial Compression Test Report

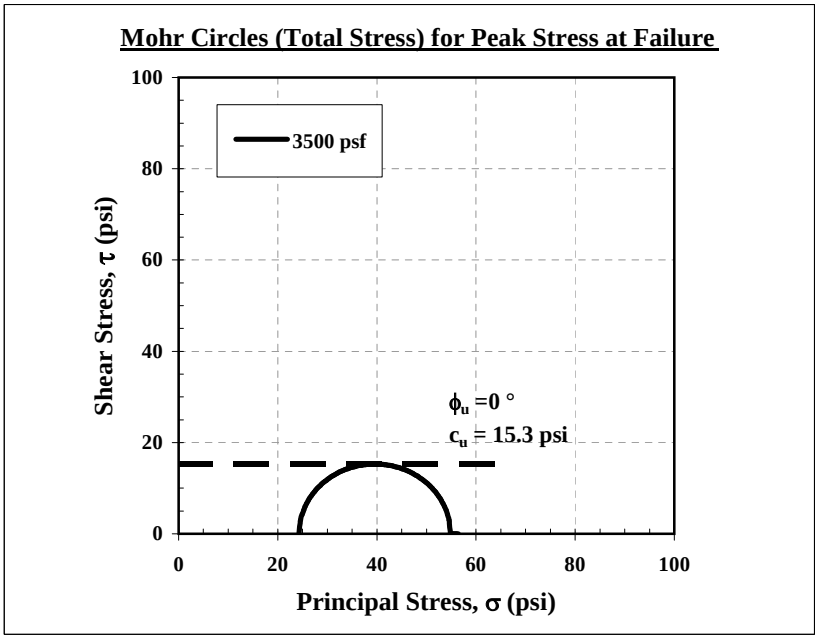
Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
TRI Log No.: E2308-12-01
Test Method: ASTM D 2850
Test Date: 4/19/2008
Sample Description: CH

Boring No.: GB2, 19'-21.5'
Sample No: - -
Type of Specimen: Undisturbed
Type of Test: Q-Test
Strain Rate (%/min): 1 % / min

Test Results	
Total Stresses (at Max. Deviator Stress)	
Friction Angle, ϕ_u (^{o}):	**0.0**
Cohesion, c_u (psi):	**15.3**



Initial Specimen Conditions		
Specimen No.		1
Confining Stress (psf)		3500
Depth/Elev (ft):		19-21.5
Diameter (in)	D_o	2.83
Height (in)	H_o	5.71
Water Content (%)	w_o	29.5
Bulk Density (pcf)	γ_{total}	120.9
Dry Density (pcf)	γ_{dry}	93.4
Saturation (%)	S_o	100.0
Void Ratio	e_o	0.77
Assumed Specific Gravity	G_s	2.65



Peak Stresses at Failure	
Maximum Deviator Stress (psi)	30.6
Axial Strain at Failure (%)	5.0
Total Stresses at Failure (Peak Stress)	
σ_1 (psi)	54.9
σ_3 (psi)	24.3

Cheng-Wei Chen 4/27/08
Quality Review/Date

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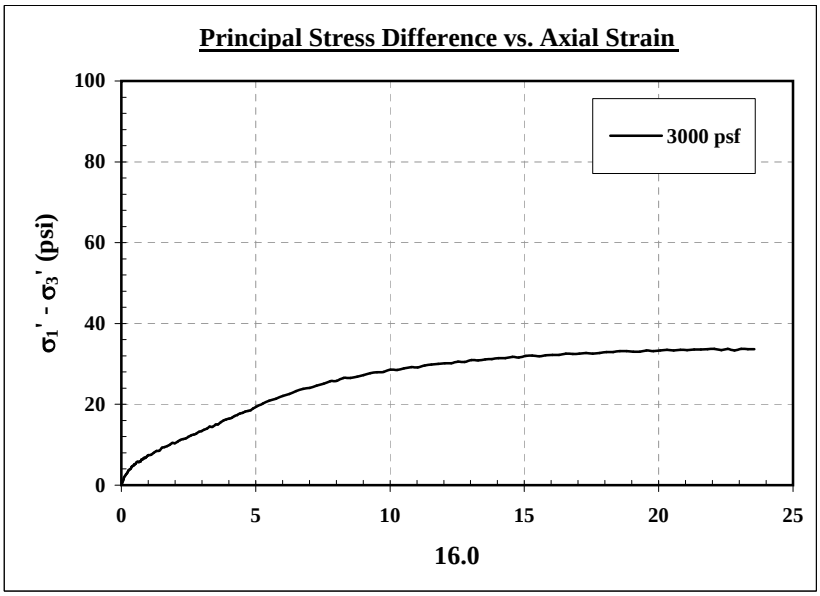
Unconsolidated-Undrained Triaxial Compression Test Report

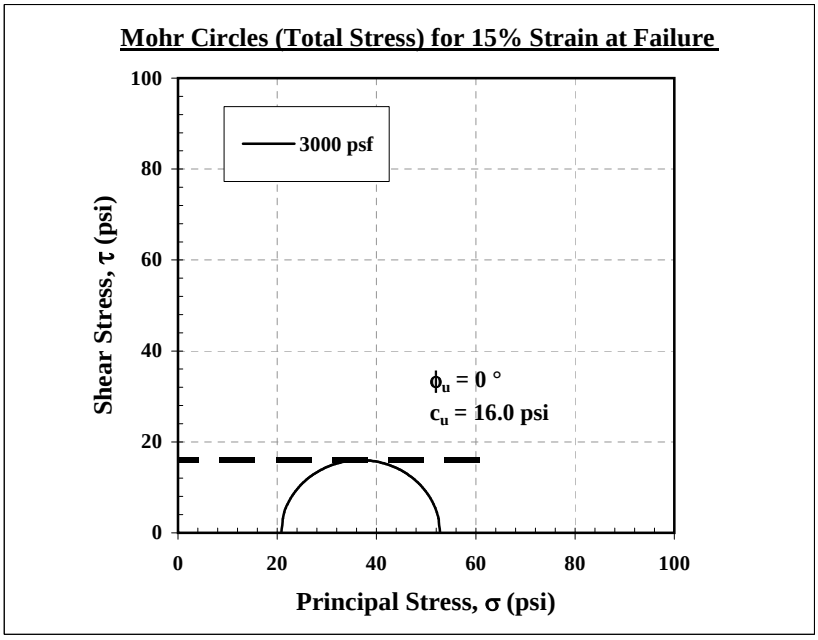
Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
TRI Log No.: E2308-12-01
Test Method: ASTM D 2850
Test Date: 4/23/2008
Sample Description: CL

Boring No.: GB7, 44.5'-47'
Sample No: - -
Type of Specimen: Undisturbed
Type of Test: Q-Test
Strain Rate (%/min): 1 % / min

Test Results	
Total Stresses	
Friction Angle, ϕ_u (^{o}):	**0**
Cohesion, c_u (psi):	**16.0**



Initial Specimen Conditions		
Specimen No.		1
Confining Stress (psf)		3000
Depth/Elev (ft):		44.5'-47'
Diameter (in)	D_o	2.81
Height (in)	H_o	5.64
Water Content (%)	w_o	25.4
Bulk Density (pcf)	γ_{total}	125.9
Dry Density (pcf)	γ_{dry}	100.5
Saturation (%)	S_o	100.0
Void Ratio	e_o	0.65
Assumed Specific Gravity	G_s	2.65



Peak Stresses at Failure (15% strain)	
Maximum Deviator Stress (psi)	32.0
Axial Strain at Failure (%)	15.1
Total Stresses at Failure (15% strain)	
σ_1 (psi)	52.8
σ_3 (psi)	20.8

Cheng-Wei Chen, 4/28/08
Quality Review/Date

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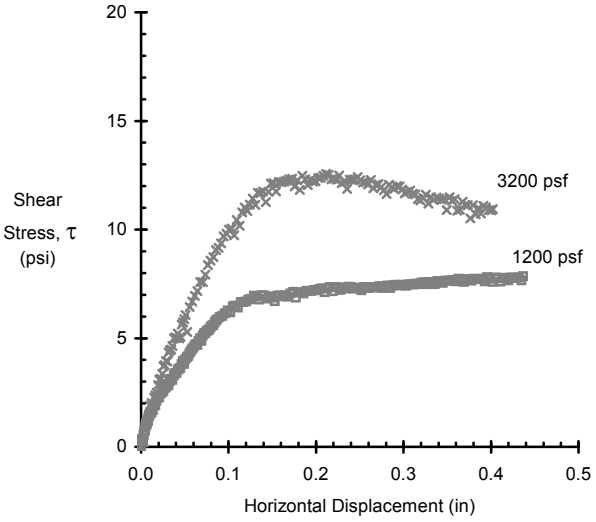
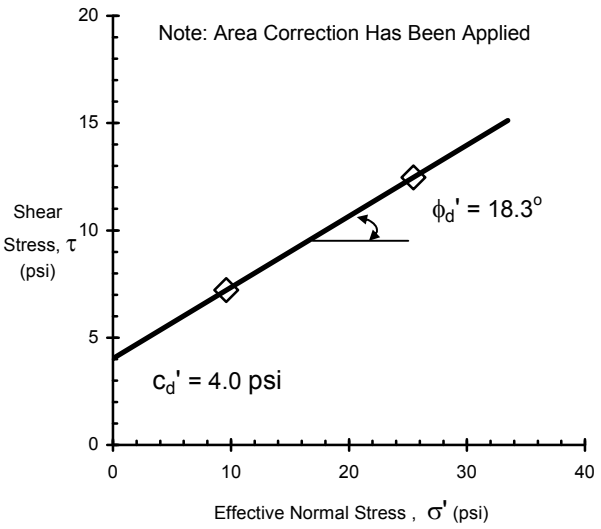
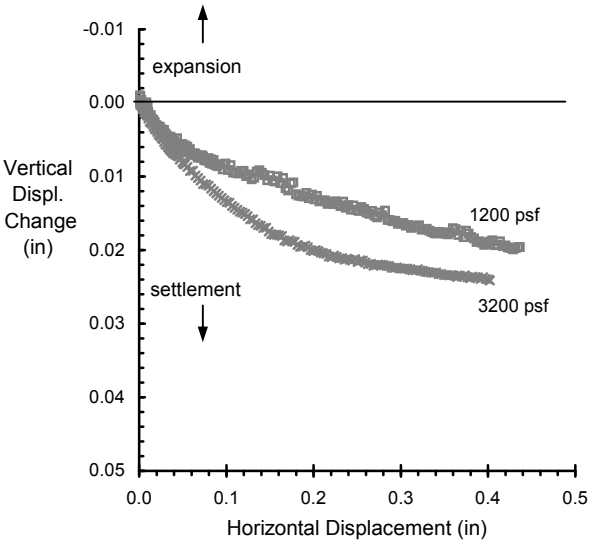
Direct Shear of Soil Under Consolidated Drained Conditions

Client: **Geosyntec Consultants**
Project: **GCA Campbell Bayou Facility**
Specimen: **GB-6, depth=12.5'-15' (Shallow Silt)**

TRI Log#: E2308-12-01
Test Method: ASTM D 3080
Test Date: 04/25/08







Sample Number		1	2	3
Initial Condition	Diameter, in	2.5	2.5	- -
	Height, in (before consol)	1.00	1.00	- -
	Water Content, %	23.9	28.2	- -
	Saturation, %	92.4	93.2	- -
	Dry Density, pcf	98.1	91.8	- -
	Void Ratio	0.69	0.80	- -
Post Consol	Height, in (prior to shear)	0.95	0.91	- -
	Final Water Content, %	24.5	27.6	- -
	Dry Density, pcf	103.3	100.5	- -
	Void Ratio	0.60	0.65	- -
Peak Normal Stress, σ' (psi)		9.6	25.5	- -
Peak Shear Stress, τ (psi)		7.2	12.5	- -
Displacement at Failure (in)		0.20	0.18	- -
Displacement rate (in/min)		0.0004	0.0004	- -

Sample Type:	Undisturbed	ϕ_d', degrees	**18.3**
G_s (assumed):	2.65	c_d', psi	**4.0**
Soil Description:	CL		

Cheng-Wei Chen, 04/30/08
Quality Review/Date

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested. TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material. TRI observes and maintains client confidentiality. TRI limits reproduction of this report, except in full, without prior approval of TRI.

May 1, 2008

Rami El-Sherbiny, Ph.D., P.E.
GeoSyntec Consultants
3600 Bee Caves Road, Suite 101
Austin, Texas 78746
Phone: 512.451.4003

Subject: Triaxial Shear Strength Testing in support of GCA Campbell Bayou Facility Project (TRI Log #: E2308-12-01)

Dear Mr. El-Sherbiny,

TRI/Environmental is pleased to present you with the triaxial shear strength results for the GB-3, 4-6.5 ft and GB-2, 4-6.5 ft borings in support of the GCA Campbell Bayou Facility. Shear strength testing was performed in general accordance with ASTM D 4767, *Standard Test Method for Consolidated Undrained Compression Test for Cohesive Soils*.

The clay specimens were extruded, trimmed and then mounted in the triaxial cells using the dry method. The filter strip cage was attached and the membrane was placed over the specimens. The specimens were then allowed to hydrate and were back-pressure saturated until a minimum B-value of 0.95 was achieved. The effective stresses were set to 5.6, 13.9 psi for the samples from boring GB-3, 4-6.5 ft. The effective stress for the sample trimmed from boring GB-2, 4-6.5 ft was 22.2 psi. Specimens were then consolidated and the strain rate was determined using the Square-root of Time Method. The specimens were sheared using a Truatwein Geotac 5k load frame at 3.0% strain per hour. Displacement, cell pressure, shear stress, and pore water pressure data were collected.

ϕ' and c' were developed using the peak stress difference (Table 1). Mohr's circles with shear strength envelopes have also been developed. A plot of the principal stress difference or deviator stress with axial strain is attached. Pore pressure measurements with axial strain are also presented in the attached figures. The p'-q diagram or Cambridge stress path and MIT stress paths are also attached. Mohr's circles and the shear strength envelopes for the total stress condition were also developed.

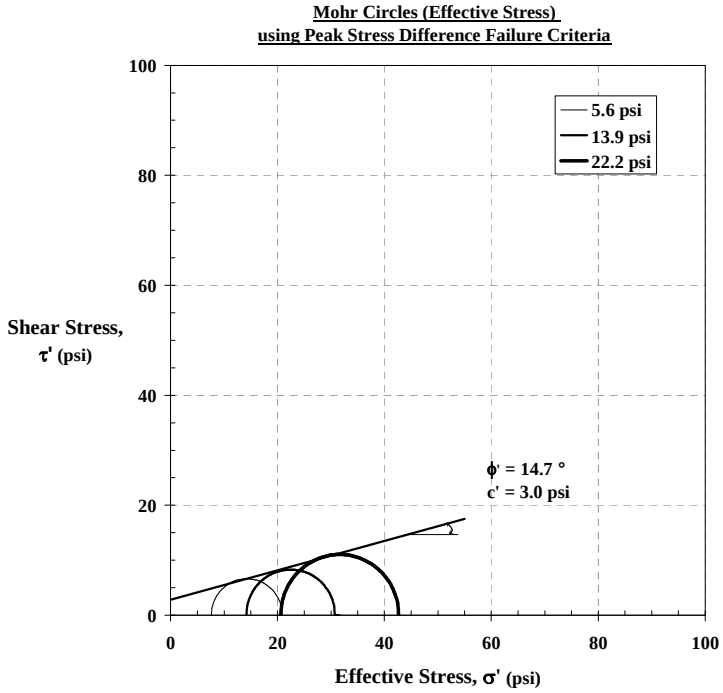
Table 1 testing summary

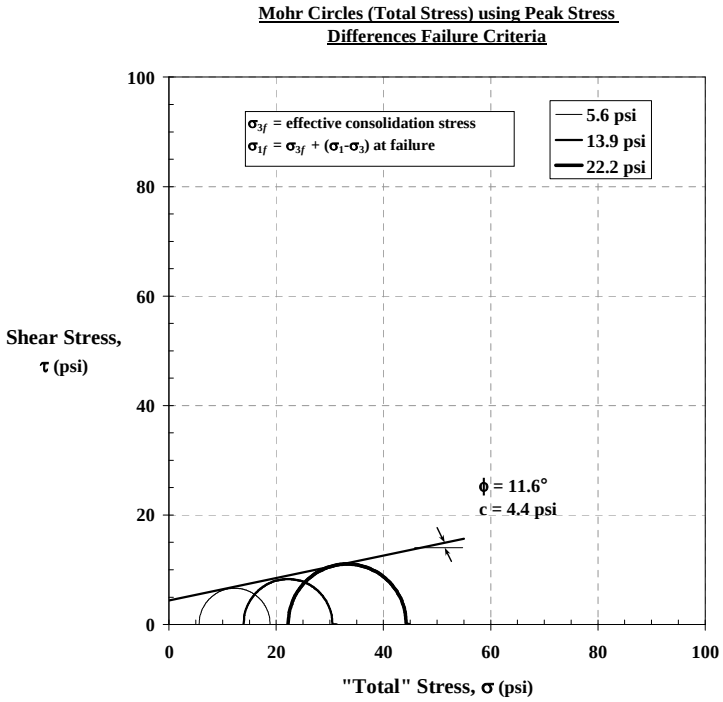
	Effective Stress	
Failure Criteria	ø, (°)	c, (psi)
Peak Deviator Stress	14.7	3.0

For your convenience a one page summary report is attached with specific specimen details and results. If you have any questions regarding the data or the testing please feel free to contact me.

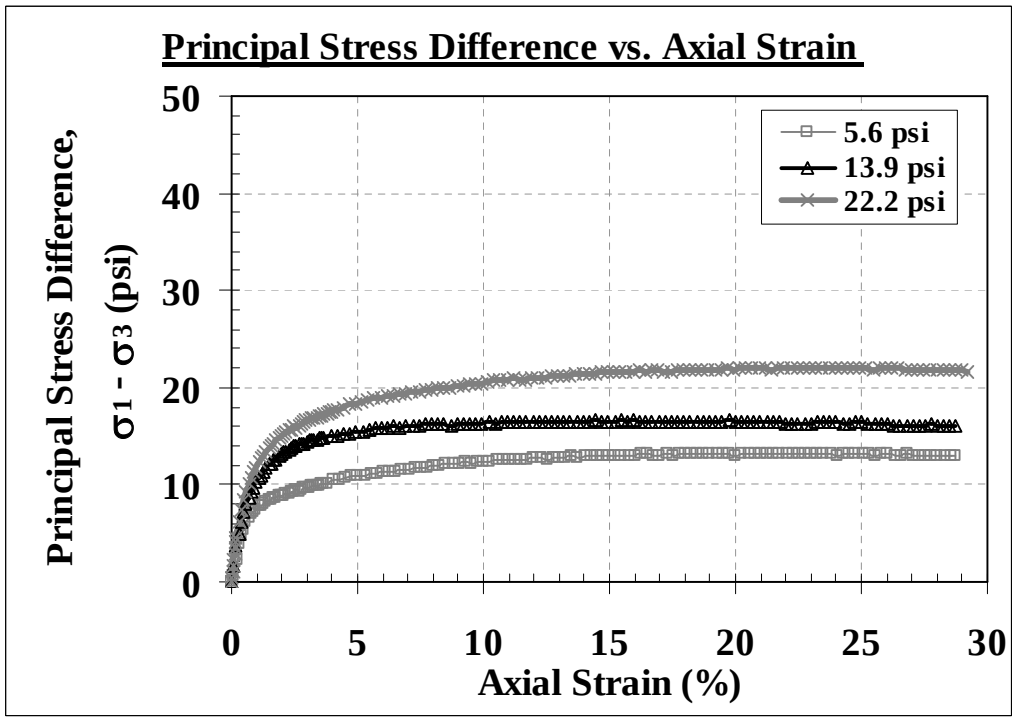
Sincerely,

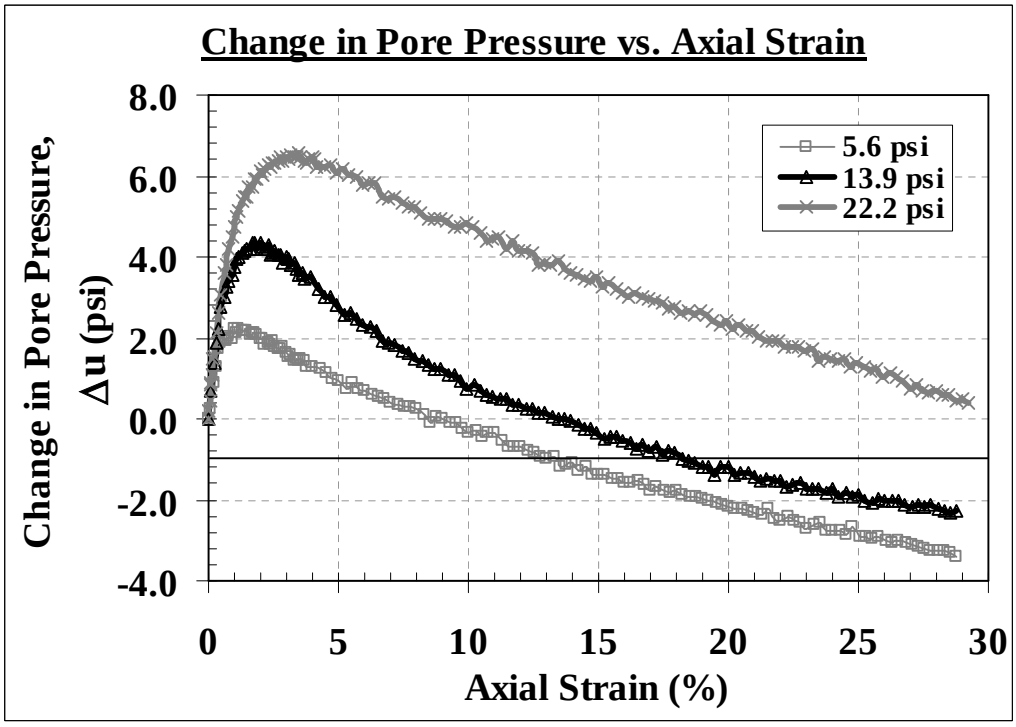
John M. Allen, E.I.T.
Director of the Geosynthetics Interaction Laboratory
TRI/Environmental,

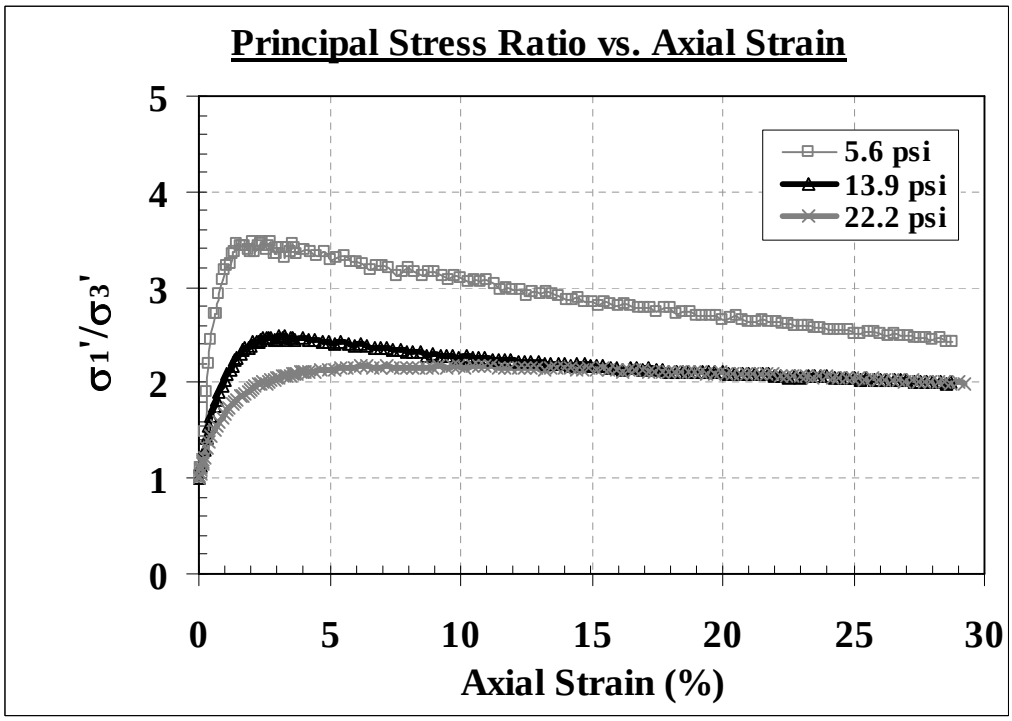


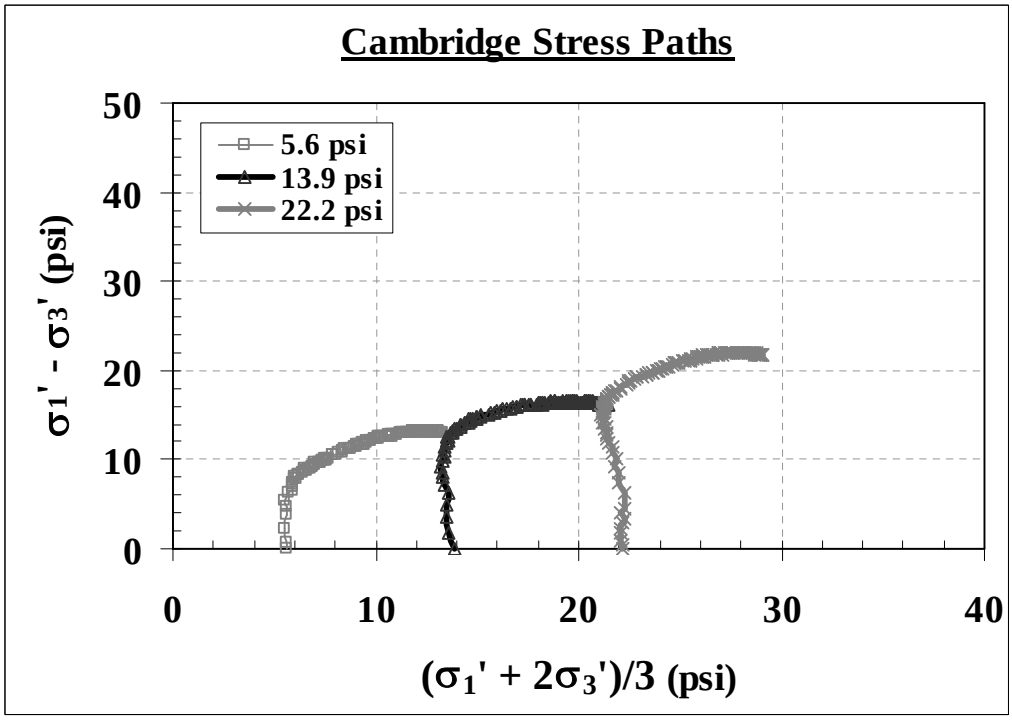


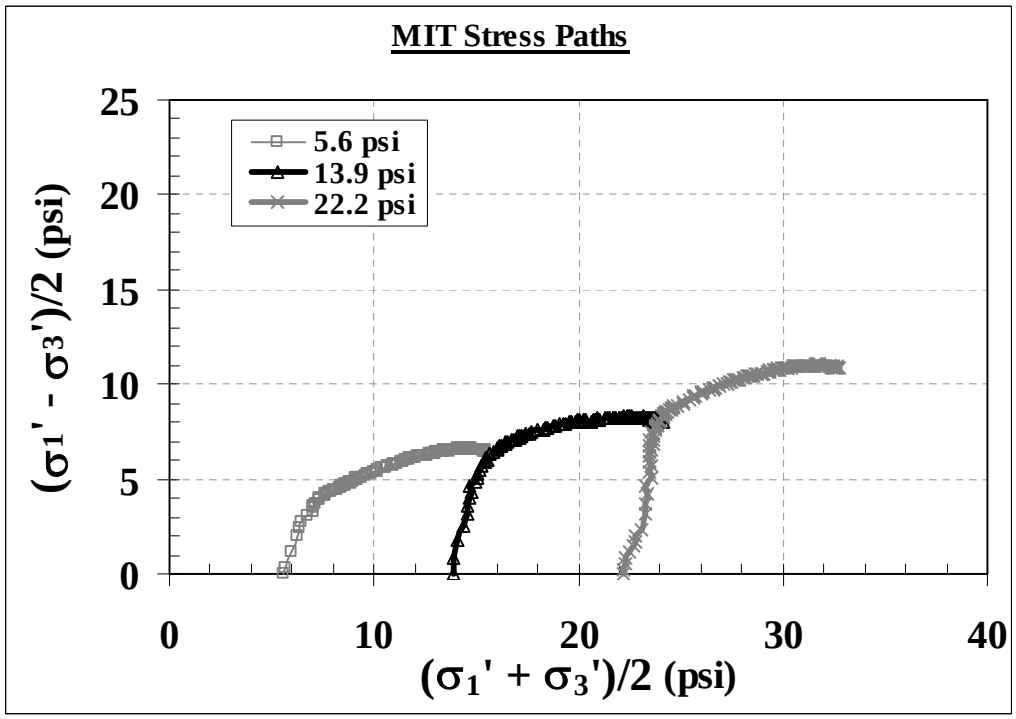
UNDISTRUBED MULTI-SPECIMEN UNDRAINED TRIAXIAL TEST
Isotropically Consolidated- Mohr's Circles
Boring GB-3, 4-6.5 ft and GB-2, 4-6.5 ft


Principal Stress Difference vs. Axial Strain
Principal Stress Difference, σ1 - σ3 (psi)
Axial Strain (%)
5.6 psi
13.9 psi
22.2 psi
0
10
20
30
40
50
0
5
10
15
20
25
30


Change in Pore Pressure vs. Axial Strain
Change in Pore Pressure, Δu (psi)
Axial Strain (%)
5.6 psi
13.9 psi
22.2 psi
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
0
5
10
15
20
25
30


Principal Stress Ratio vs. Axial Strain
5.6 psi
13.9 psi
22.2 psi
σ1'/σ3'
Axial Strain (%)
0
1
2
3
4
5
0
5
10
15
20
25
30


Cambridge Stress Paths
5.6 psi
13.9 psi
22.2 psi
σ1' - σ3' (psi)
(σ1' + 2σ3')/3 (psi)
0
10
20
30
40
50
0
10
20
30
40



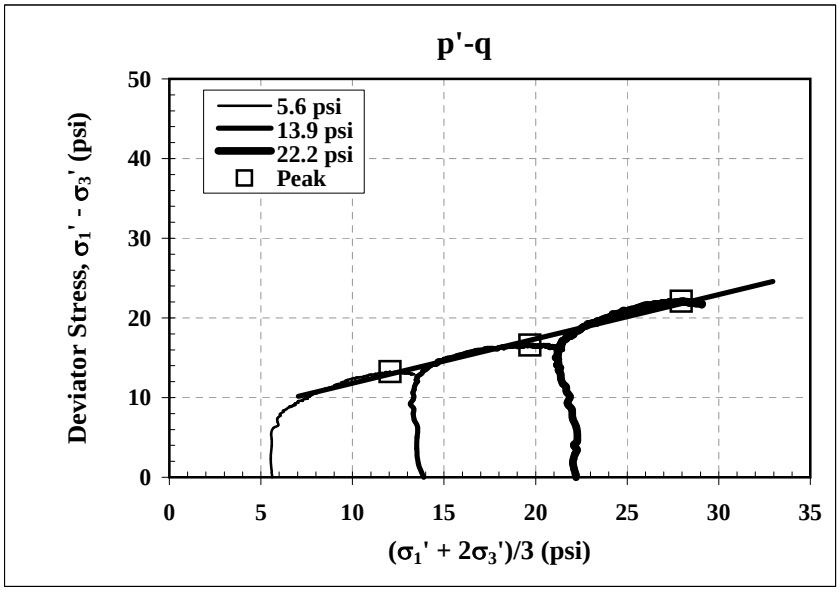
GB-3, 4-6.5 ft., σ' = 5.6 psi	GB-3, 4-6.5 ft., σ' = 13.9 psi	GB-2, 4-6.5 ft., σ' = 22.2 psi

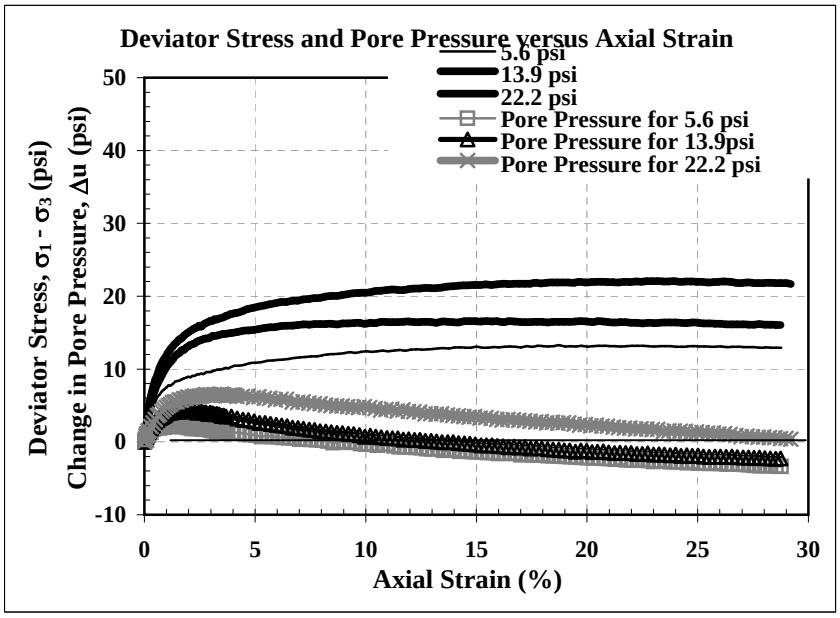
Figure 1 post test specimens

Consolidated-Undrained Triaxial Compression Test Report

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
TRI Log No.: E2308-12-01
Test Method: ASTM D 4767
Test Date: 4/26/2008
Sample Description: CL

Boring No.: GB-3, 4-6.5' & GB-2, 4'-6.5'
Sample No:
Type of Specimen: Undisturbed
Type of Test: CU R-bar
Strain Rate (%/hr): 3 % / hr





Test Results	
"Total" Stresses	
Friction Angle, ϕ (°):	**11.6**
Cohesion, c (psi):	**4.4**
Effective Stresses	
Friction Angle, ϕ' (°):	**14.7**
Cohesion, c' (psi):	**3.0**

Initial Specimen Conditions				
Specimen No.		1 (GB-3)	2 (GB-3)	3 (GB-2)
Effective Stress (psi)		5.6	13.9	22.2
Depth/Elev (ft):		4'-6.5'	4'-6.5'	4'-6.5'
Diameter (in)	D_o	2.82	2.83	2.80
Height (in)	H_o	5.78	5.62	5.69
Water Content (%)	w_o	18.5	21.1	17.9
Bulk Density (pcf)	WD_o	125.6	128.1	131.8
Dry Density (pcf)	DD_o	106.0	105.7	111.7
Saturation (%)	S_o	87.5	99.2	98.7
Void Ratio	e_o	0.56	0.56	0.48
Assumed Specific Gravity	G_s	2.65	2.65	2.65
B-Coefficient	B	0.99	0.97	0.98
Specimen Conditions after Consolidation				
Water Content (%)	w_f	24.5	20.3	20.8
Dry Density (pcf)	DD_1	100.3	107.5	106.6
Void Ratio	e_1	0.65	0.54	0.55
Area (in^2)	A_1	6.26	6.25	6.13

Peak Stresses at Failure			
Deviator Stress (psi)	13.3	16.6	22.1
"Total" Stresses at Failure (Peak)			
σ_{1f} (psi)	18.86	30.49	44.29
σ_{3f} (psi)	5.61	13.90	22.21
Effective Stresses at Failure (Peak)			
σ'_{1f} (psi)	20.89	30.76	42.68
σ'_{3f} (psi)	7.63	14.17	20.60

Undisturbed specimens saturation completed using dry method. Failure determined using peak stress difference.

Cheng-Wei Chen, 4/30/08
Quality Review/Date

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested. TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material. TRI observes and maintains client confidentiality. TRI limits reproduction of this report, except in full, without prior approval of TRI.

May 1, 2008

Rami El-Sherbiny, Ph.D., P.E.
GeoSyntec Consultants
3600 Bee Caves Road, Suite 101
Austin, Texas 78746
Phone: 512.451.4003

Subject: Triaxial Shear Strength Testing in support of GCA Campbell Bayou Facility Project (TRI Log #: E2308-12-01)

Dear Mr. El-Sherbiny,

TRI/Environmental is pleased to present you with the triaxial shear strength results for the GB-3, 24.5-27.0 ft and GB-3, 29.0-31.5 ft borings in support of the GCA Campbell Bayou Facility. Shear strength testing was performed in general accordance with ASTM D 4767, *Standard Test Method for Consolidated Undrained Compression Test for Cohesive Soils*.

The clay specimens were extruded, trimmed and then mounted in the triaxial cells using the dry method. The filter strip cage was attached and the membrane was placed over the specimens. The specimens were then allowed to hydrate and were back-pressure saturated until a minimum B-value of 0.95 was achieved. The effective stresses were set to 13.9, 27.8 psi for the samples from boring GB-3, 24.5-27.0 ft. The effective stress for the sample trimmed from boring GB-3, 29.0-31.5 ft was 41.7 psi. Specimens were then consolidated and the strain rate was determined using the Square-root of Time Method. The specimens were sheared using a Truatwein Geotac 5k load frame at 10.0% strain per hour. Displacement, cell pressure, shear stress, and pore water pressure data were collected.

ϕ' and c' were developed using the peak stress difference (Table 1). Mohr's circles with shear strength envelopes have also been developed. A plot of the principal stress difference or deviator stress with axial strain is attached. Pore pressure measurements with axial strain are also presented in the attached figures. The p'-q diagram or Cambridge stress path and MIT stress paths are also attached. Mohr's circles and the shear strength envelopes for the total stress condition were also developed.

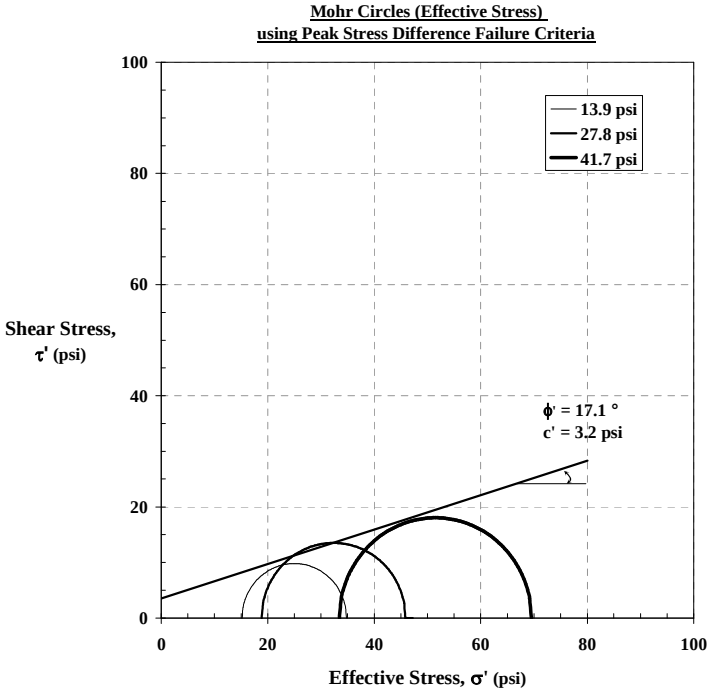
Table 1 testing summary

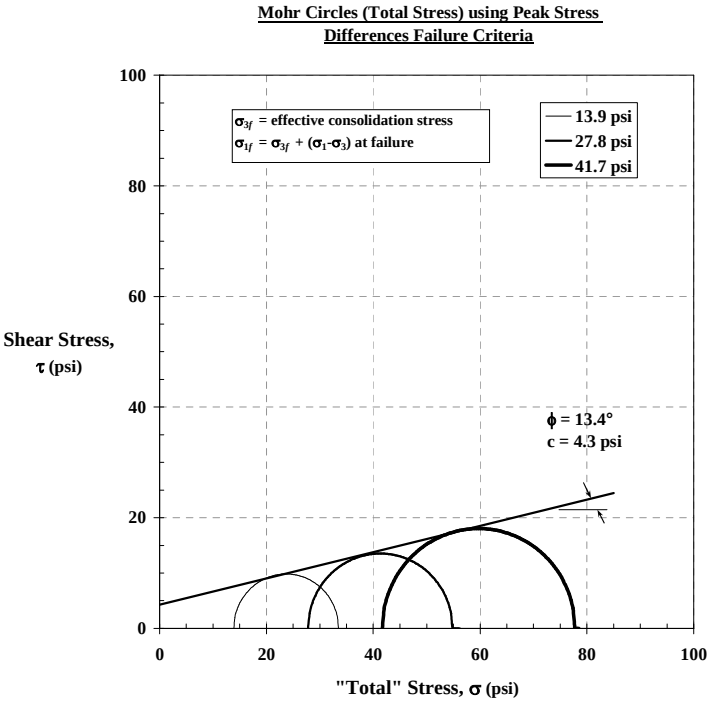
	Effective Stress	
Failure Criteria	ø, (°)	c, (psi)
Peak Deviator Stress	17.1	3.2

For your convenience a one page summary report is attached with specific specimen details and results. If you have any questions regarding the data or the testing please feel free to contact me.

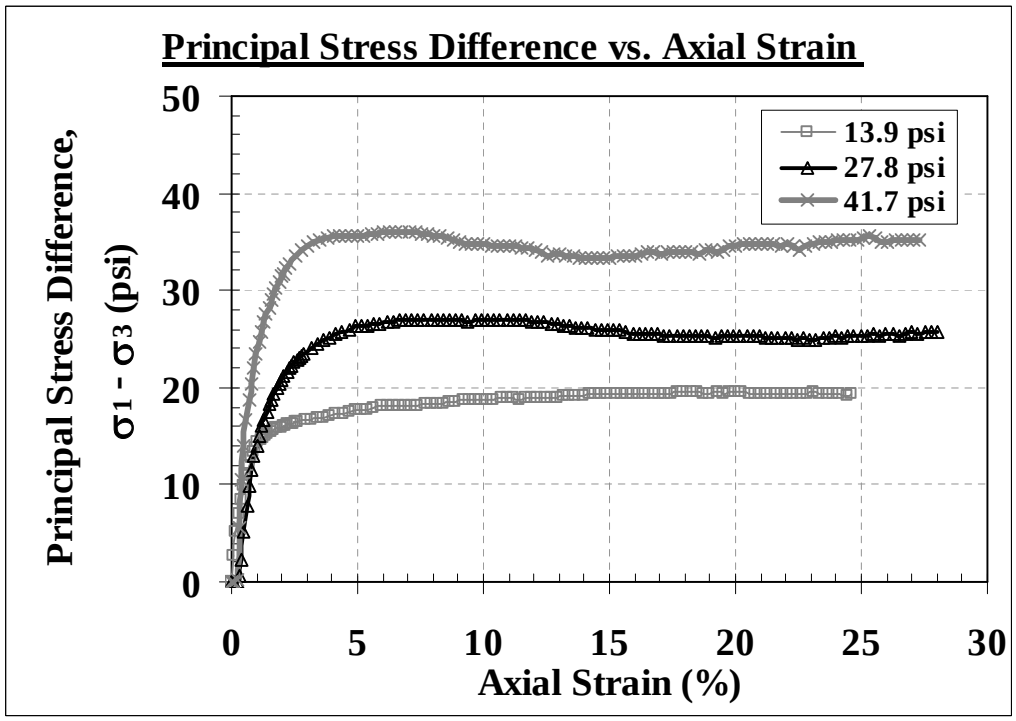
Sincerely,

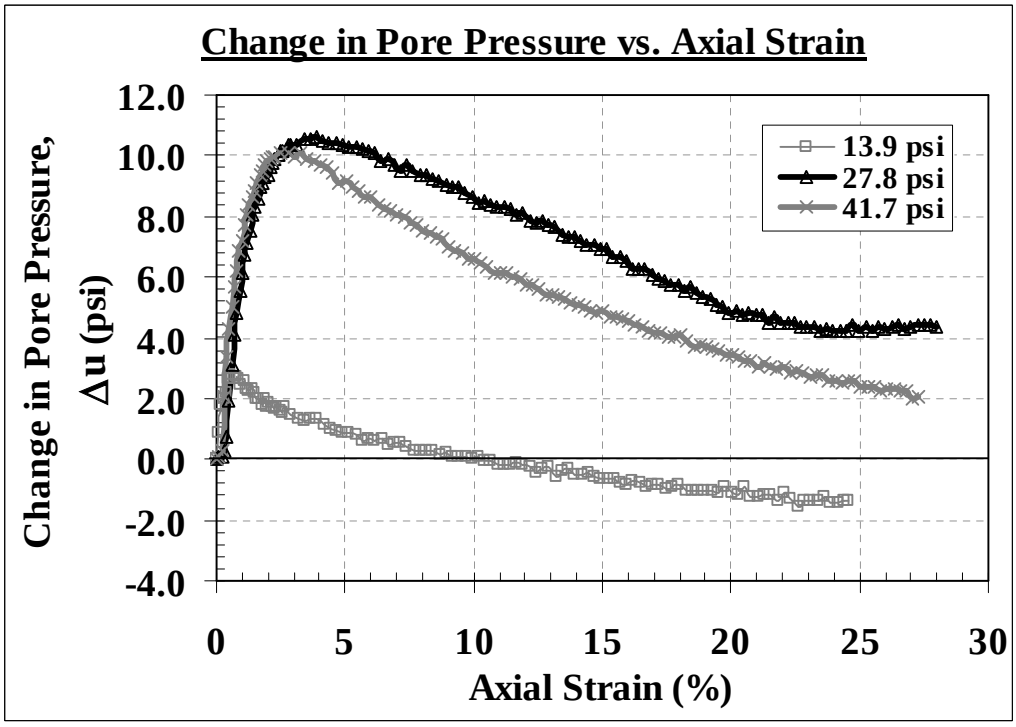
John M. Allen, E.I.T.
Director of the Geosynthetics Interaction Laboratory
TRI/Environmental,

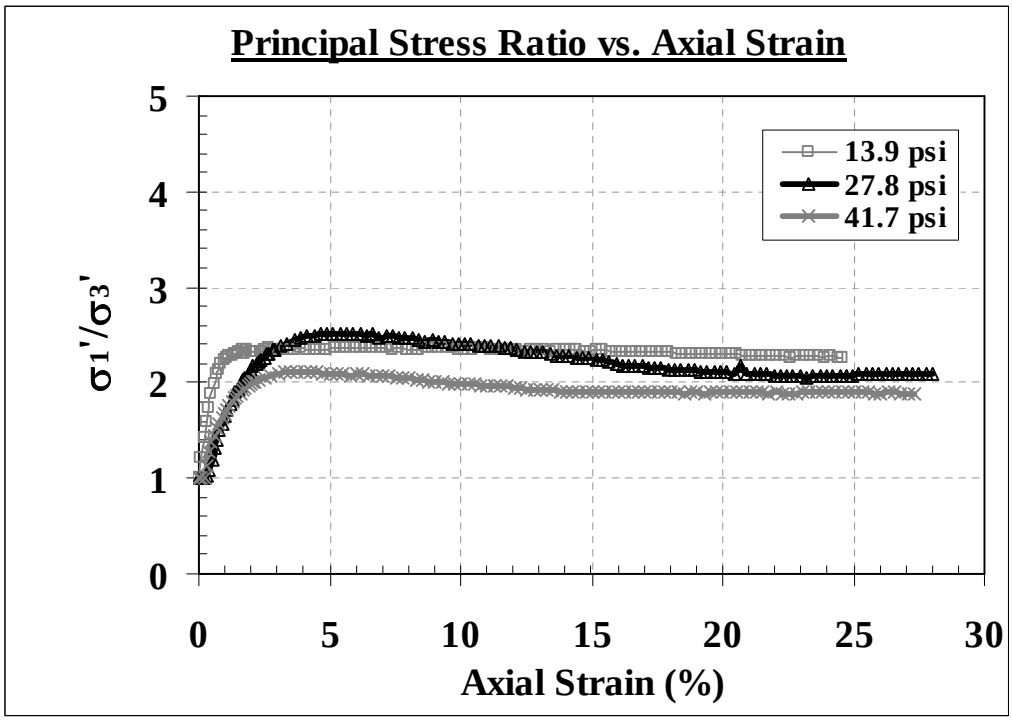


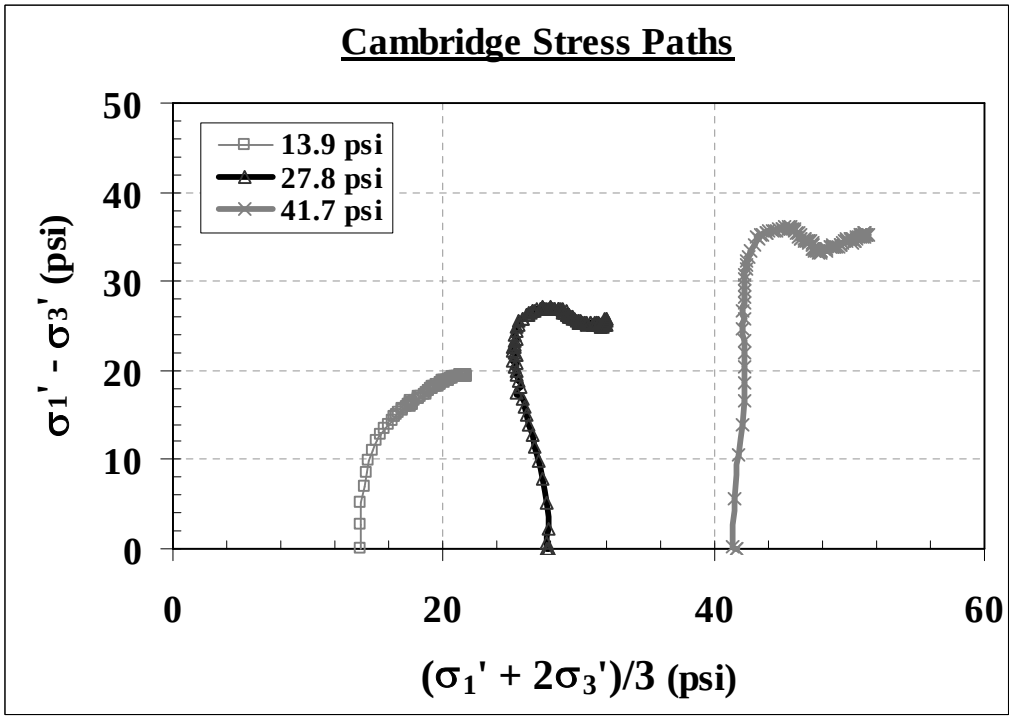


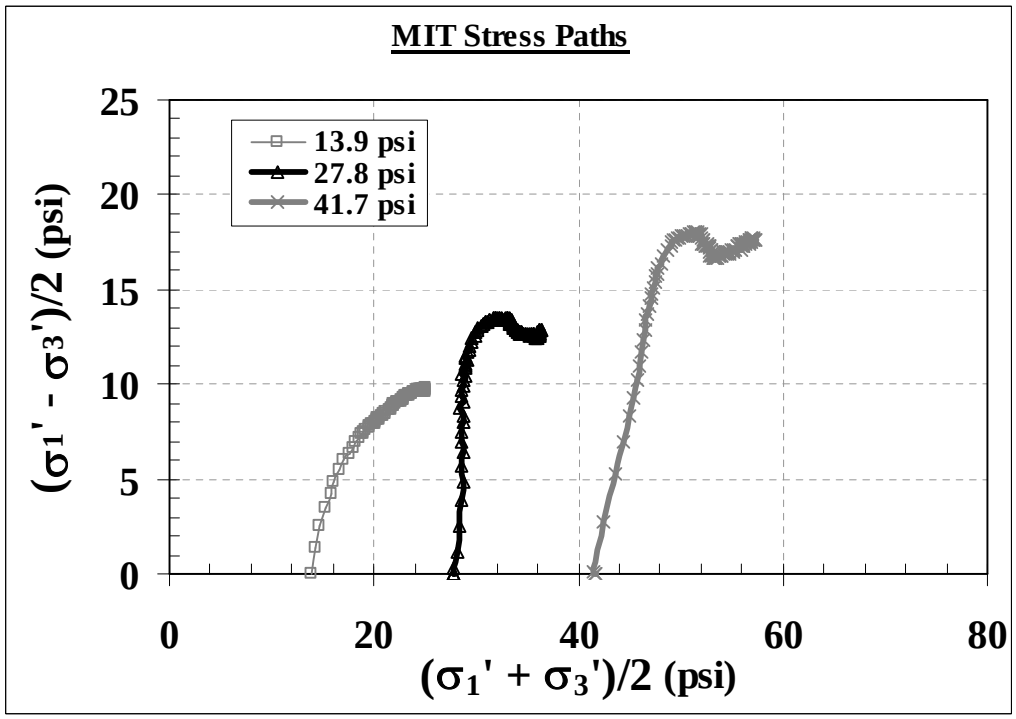
UNDISTRUBED MULTI-SPECIMEN UNDRAINED TRIAXIAL TEST
Isotropically Consolidated- Mohr's Circles
Boring GB-3, 24.5-27.0 ft and GB-3, 29.0-31.5 ft

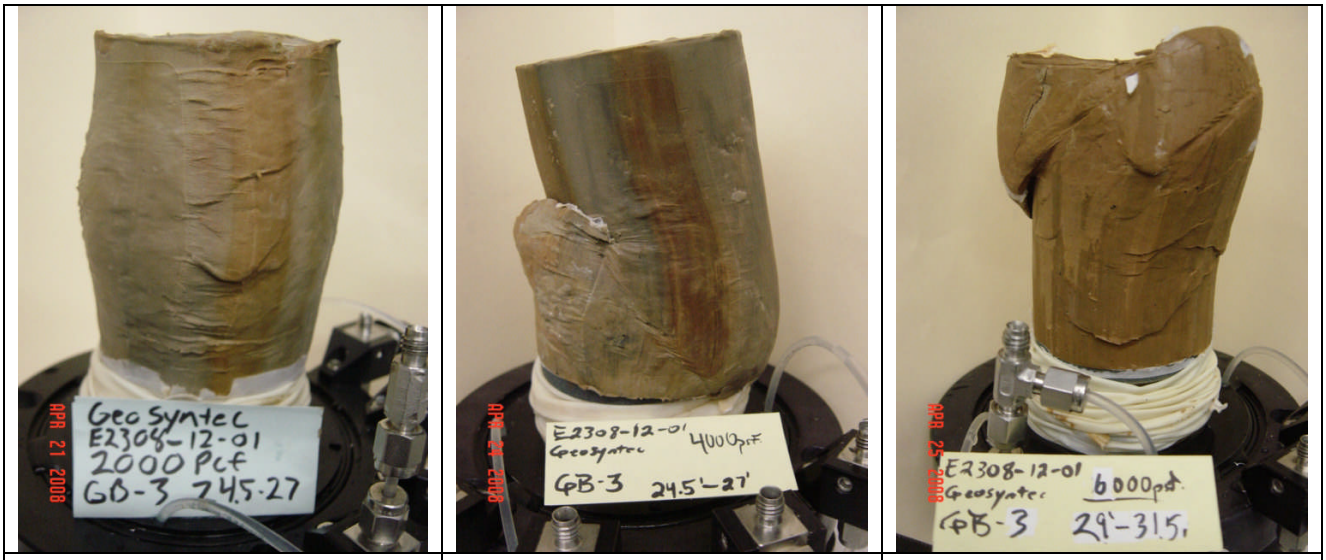

Principal Stress Difference vs. Axial Strain
Principal Stress Difference, σ1 - σ3 (psi)
Axial Strain (%)
13.9 psi
27.8 psi
41.7 psi
0
10
20
30
40
50
0
5
10
15
20
25
30


Change in Pore Pressure vs. Axial Strain
Change in Pore Pressure, Δu (psi)
Axial Strain (%)
13.9 psi
27.8 psi
41.7 psi
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
0
5
10
15
20
25
30


Principal Stress Ratio vs. Axial Strain
13.9 psi
27.8 psi
41.7 psi
σ1'/σ3'
Axial Strain (%)
0
1
2
3
4
5
0
5
10
15
20
25
30


Cambridge Stress Paths
13.9 psi
27.8 psi
41.7 psi
σ1' - σ3' (psi)
(σ1' + 2σ3')/3 (psi)
0
10
20
30
40
50
0
20
40
60





GB-3, 24.5-27 ft., σ' = 13.9 psi	GB-3, 24.5-27 ft., σ' = 27.8 psi	GB-3, 29-31.5 ft., σ' = 41.7 psi

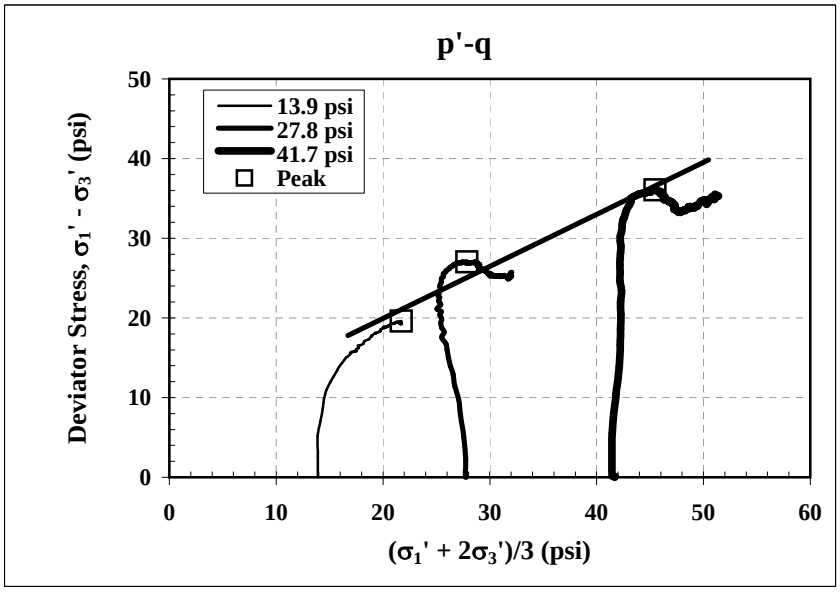
Figure 1 post test specimens

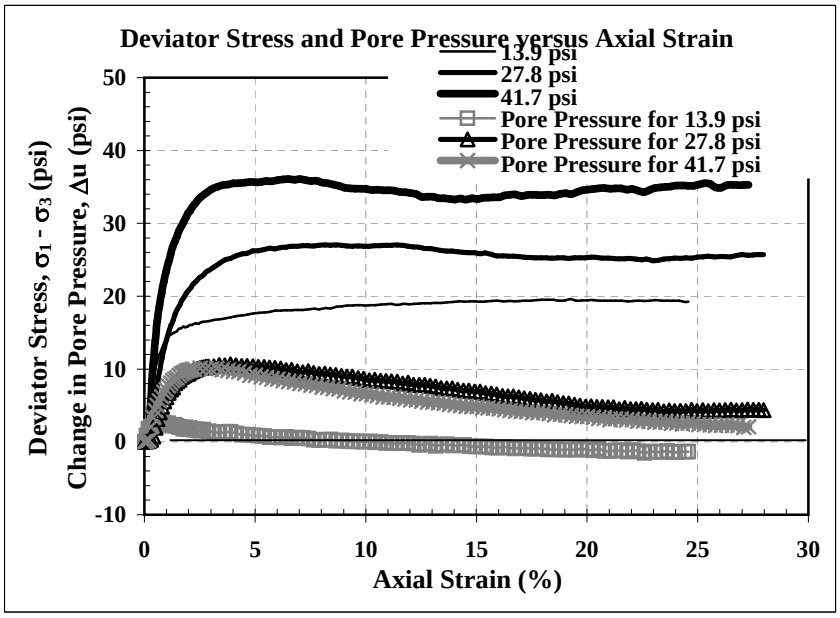
Consolidated-Undrained Triaxial Compression Test Report

Client: Geosyntec Consultants
Project: GCA Campbell Bayou Facility
TRI Log No.: E2308-12-01
Test Method: ASTM D 4767
Test Date: 4/21/2008
Sample Description: CL

Boring No.: GB-3, 24.5'-27' & GB-3, 39'-31.5'
Sample No:
Type of Specimen: Undisturbed
Type of Test: CU R-bar
Strain Rate (%/hr): 10 % / hr

Test Results	
"Total" Stresses	
Friction Angle, ϕ (°):	**13.4**
Cohesion, c (psi):	**4.3**
Effective Stresses	
Friction Angle, ϕ' (°):	**17.1**
Cohesion, c' (psi):	**3.2**





Initial Specimen Conditions				
Specimen No.		1	2	3
Effective Stress (psi)		13.9	27.8	41.7
Depth/Elev (ft):		24.5'-27'	24.5'-27'	29'-31.5'
Diameter (in)	D_o	2.83	2.82	2.82
Height (in)	H_o	5.45	5.61	5.63
Water Content (%)	w_o	19.5	18.3	20.9
Bulk Density (pcf)	WD_o	126.9	125.7	125.5
Dry Density (pcf)	DD_o	106.2	106.2	103.9
Saturation (%)	S_o	92.5	87.0	93.2
Void Ratio	e_o	0.56	0.56	0.59
Assumed Specific Gravity	G_s	2.65	2.65	2.65
B-Coefficient	B	0.99	0.97	0.98
Specimen Conditions after Consolidation				
Water Content (%)	w_f	21.1	18.9	25.1
Dry Density (pcf)	DD_1	106.0	110.2	99.4
Void Ratio	e_1	0.56	0.50	0.66
Area (in^2)	A_1	6.24	6.16	6.04

Peak Stresses at Failure			
Deviator Stress (psi)	19.6	27.0	36.1
"Total" Stresses at Failure (Peak)			
σ_{1f} (psi)	33.50	54.83	77.76
σ_{3f} (psi)	13.90	27.80	41.70
Effective Stresses at Failure (Peak)			
σ'_{1f} (psi)	34.79	45.88	69.52
σ'_{3f} (psi)	15.18	18.85	33.45

Undisturbed specimens saturation completed using dry method. Failure determined using peak stress difference.

Cheng-Wei Chen, 4/29/08
Quality Review/Date

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested. TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material. TRI observes and maintains client confidentiality. TRI limits reproduction of this report, except in full, without prior approval of TRI.

9063 Bee Caves Road □ Austin, TX 78733-6201 □ (512) 263-2101 □ (512) 263-2558 □ 1-800-880-TEST

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

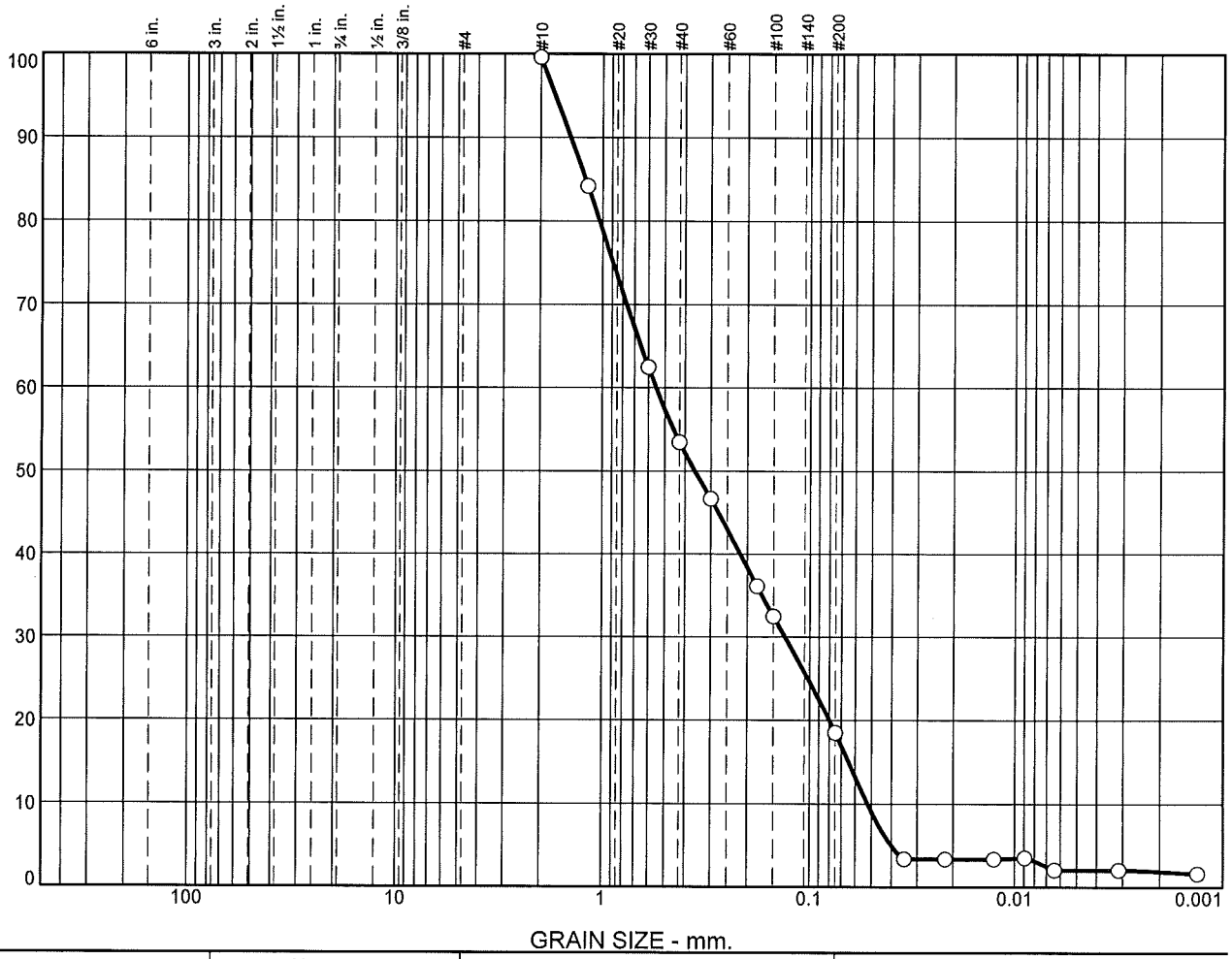
Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

APPENDIX 2.2

Laboratory Results from Entact (2014)

This report contains test results of randomly selected material. Engineering properties may differ during the day's construction activity. The report shall not be alter

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○					46.1	35.0	16.4	2.1

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	49	44	1.2109	0.5502	0.3582	0.1319	0.0646	0.0523	0.60	10.52

Material Description	USCS	AASHTO
○ Gray silty sand	SM	A-2-5(0)

Project No. 1754 **Client:** Entact, LLC

Project: Malone Superfund Site

○ **Source of Sample:** SPCO3 **Sample Number:** 1

Remarks:

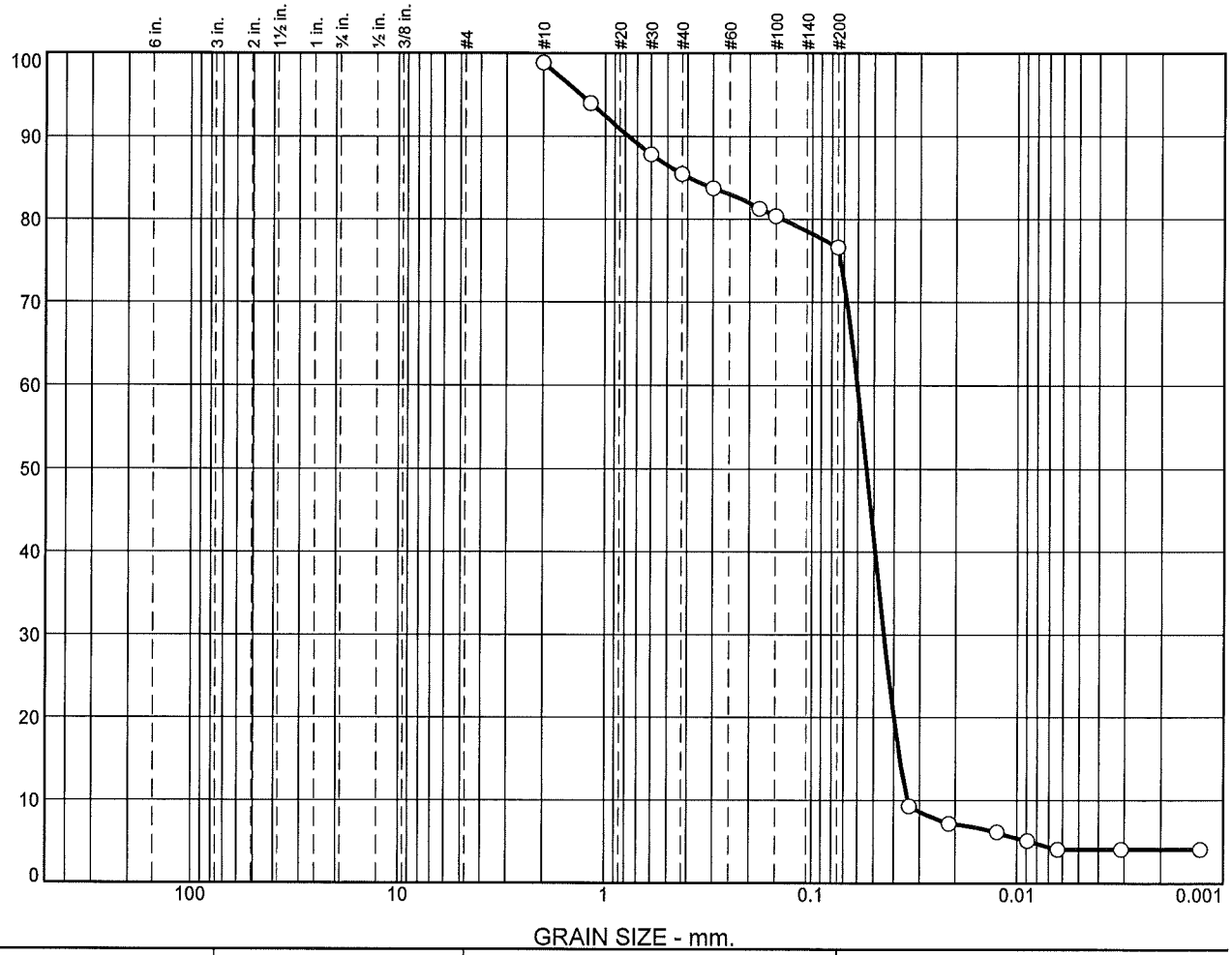
○ Test methods: ASTM D422, D4318

Kenall Inc.
Geotechnical, Environmental & Materials Engineers

Figure

This report contains test results of randomly selected material. Engineering properties may differ during the day's construction activity. The report shall not be alter

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○					13.3	8.9	72.5	4.1

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	48	41	0.3916	0.0603	0.0545	0.0447	0.0373	0.0343	0.96	1.76

	Material Description	USCS	AASHTO
○	Gray sandy silt	ML	A-5(8)

Project No. 1754 **Client:** Entact, LLC

Project: Malone Superfund Site

○ **Source of Sample:** SPCO4 **Sample Number:** 1

Remarks:

○ Test methods: ASTM D422, D4318

Kenall Inc.

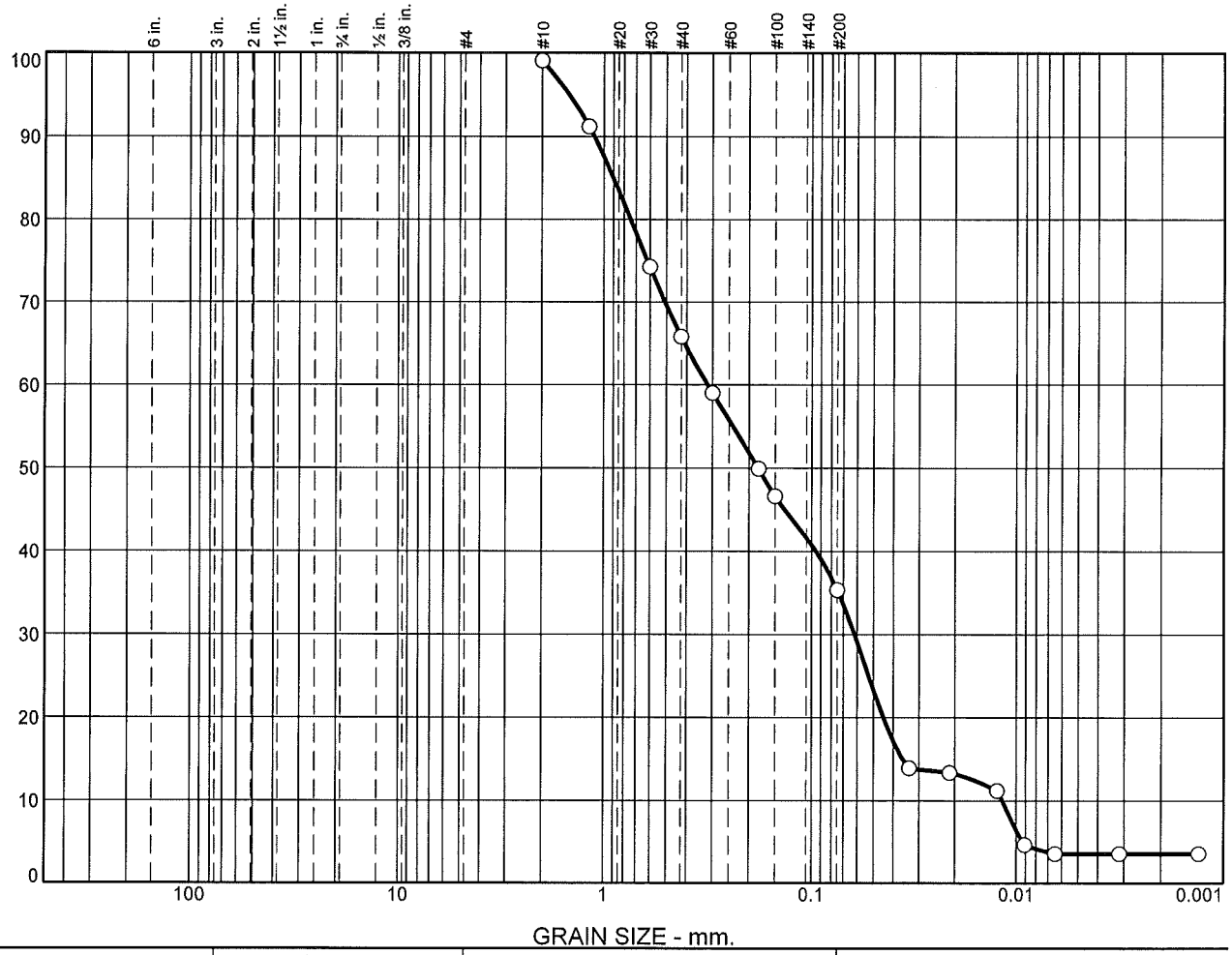
Figure

Tested By: Mario Barbosa

Kris D. Prasad

This report contains test results of randomly selected material. Engineering properties may differ during the day's construction activity. The report shall not be alter

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○					33.3	30.4	31.8	3.6

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	NP	NP	0.8997	0.3167	0.1809	0.0618	0.0360	0.0117	1.03	27.06

Material Description	USCS	AASHTO
○ Dark gray silty sand	NP	A-2-4(0)

Project No. 1754 **Client:** Entact, LLC

Project: Malone Superfund Site

○ **Source of Sample:** OPCO1 **Sample Number:** 1

Remarks:

○ Test methods: ASTM D422

Kenall Inc.

Geotechnical, Environmental & Materials Engineers

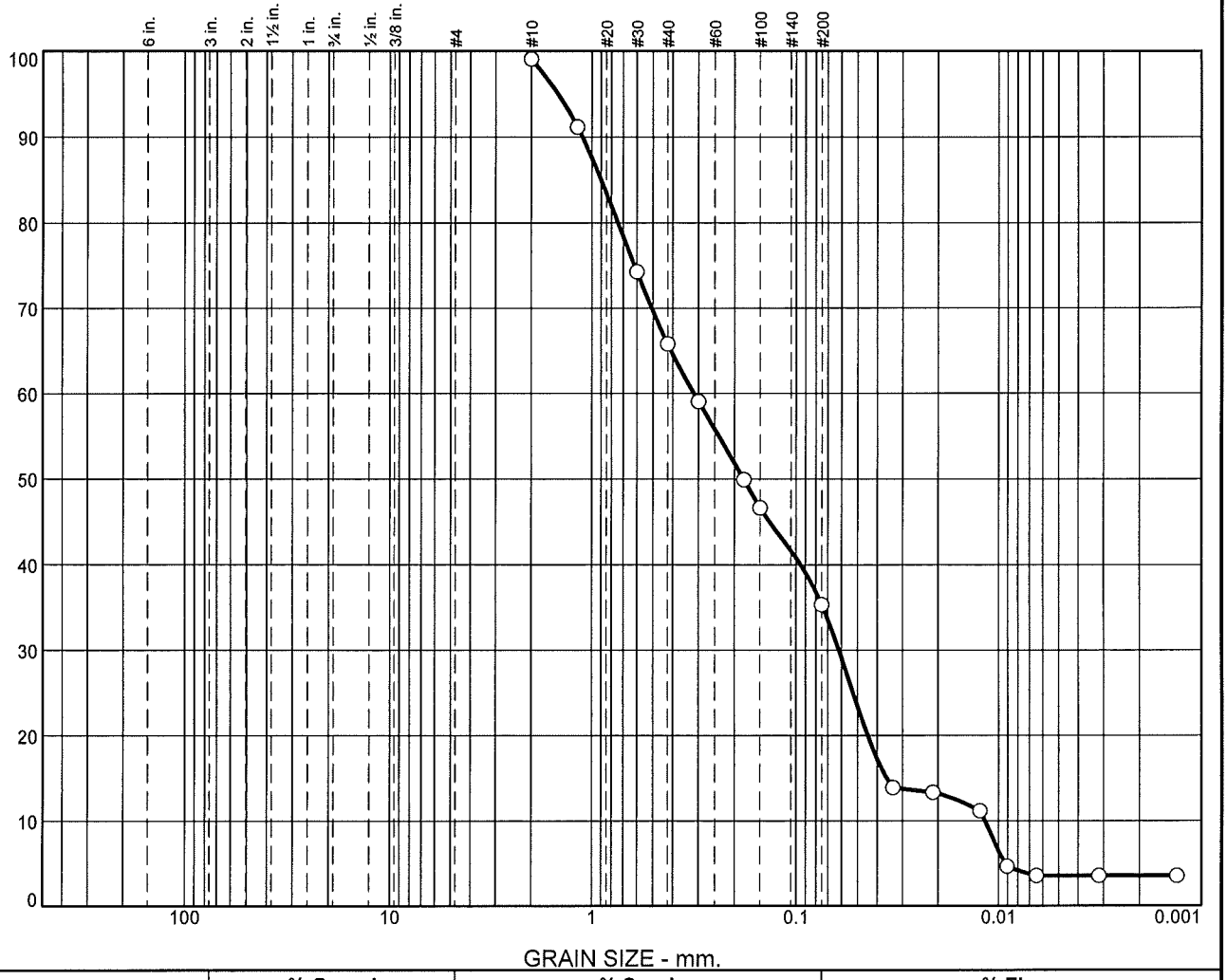
Figure

Tested By: Mario Barbosa

Kris D. Prasad

This report contains test results of randomly selected material. Engineering properties may differ during the day's construction activity. The report shall not be altered or r

Particle Size Distribution Report



	% +3"	% Gravel		% Sand			% Fines	
		Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
○					33.3	30.4	31.8	3.6

	LL	PL	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
○	NP	NP	0.8997	0.3167	0.1809	0.0618	0.0360	0.0117	1.03	27.06

Material Description	USCS	AASHTO
○ Dark gray sandy clay	SM	A-2-4(0)

Project No. 1754 **Client:** Entact, LLC

Project: Malone Superfund Site

○ **Source of Sample:** OPCO1 **Sample Number:** 1

Remarks:

ASTM D422, D4318

Kenall Inc.

Figure

Direct Shear Test (ASTM D3080)

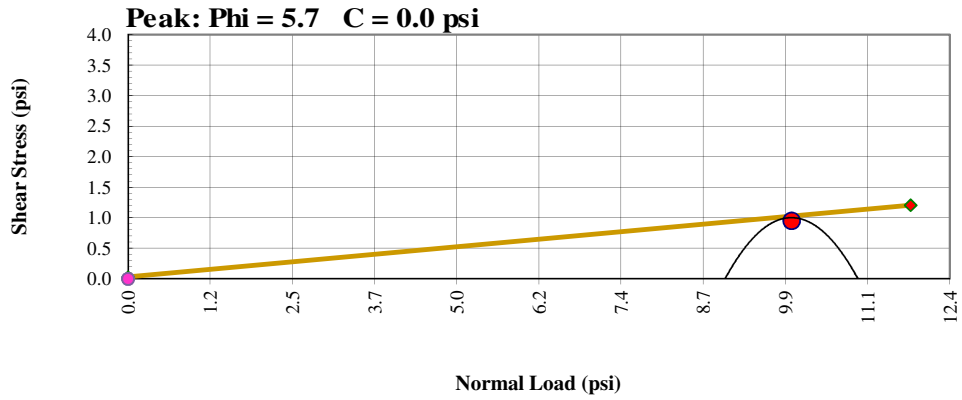
Date

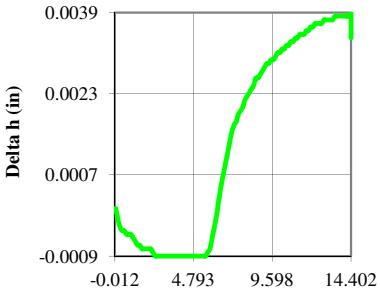
Checked By

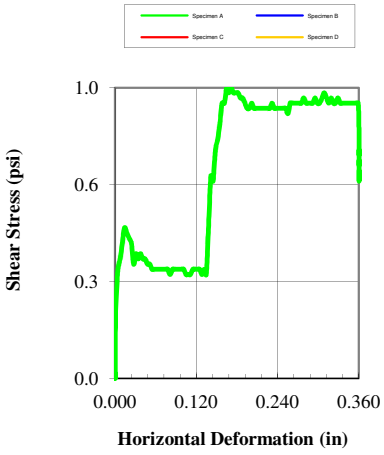
Date

Date

Tested By







Initial	Specimen A	B	C	D
Moisture (%)	46.63			
Density (pcf)	57.80			
Void Ratio	1.862			
Saturation (%)	66.35			
Diameter (in)	2.500			
Height (in)	1.000			

Final	A	B	C	D
Moisture (%)	65.92			
Density (pcf)	61.90			
Void Ratio	1.673			
Saturation (%)	100.00			
Diameter (in)	2.500			
Height (in)	0.999			
Normal Stress (psi)	10.0			
Peak Stress (psi)	1.0			
Residual Stress (psi)				
Strain (%)	14.402			
Rate (in/min)	0.02			

Project Date	
Date	8/13/14

Project:	Malone Superfund				
Location:	SPC03				
Project Number:	1754	N/A	N/A	N/A	N/A
Boring Number					
Sample Number:	1				
Depth:					
Sample Type:	Remolded	Failure Photographs			
Description:					
Test Type:	Direct Shear				
Remarks:					

Direct Shear Test (ASTM D3080)

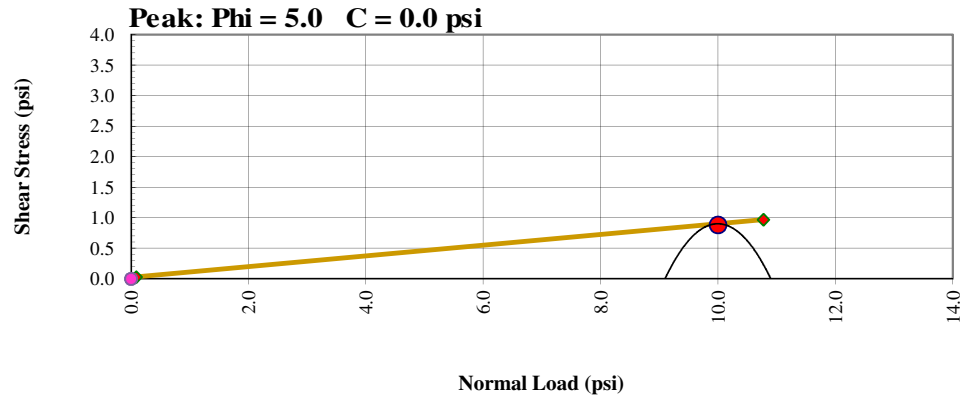
Date

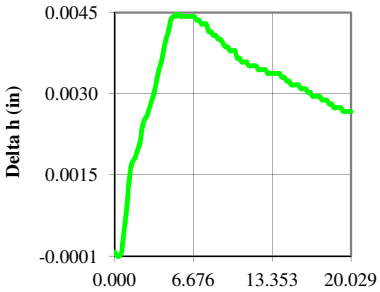
Checked By

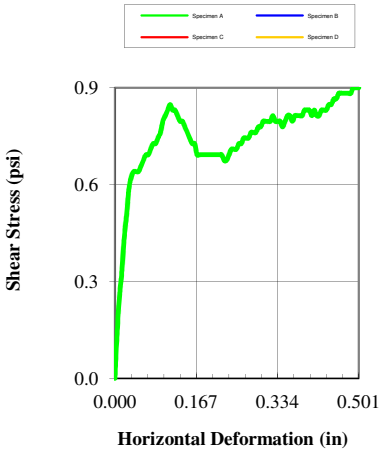
Date

Date

Tested By







Initial	Specimen A	B	C	D
Moisture (%)	38.07			
Density (pcf)	58.90			
Void Ratio	1.809			
Saturation (%)	55.78			
Diameter (in)	2.500			
Height (in)	1.000			

Final	A	B	C	D
Moisture (%)	59.10			
Density (pcf)	57.41			
Void Ratio	1.881			
Saturation (%)	83.15			
Diameter (in)	2.500			
Height (in)	1.001			
Normal Stress (psi)	10.0			
Peak Stress (psi)	0.9			
Residual Stress (psi)				
Strain (%)	20.029			
Rate (in/min)	0.02			

Project Date	
Date	8/13/14

Project:	Malone Superfund E7888	N/A	N/A	N/A	N/A
Location:	SPC04				
Project Number:	1754				
Boring Number					
Sample Number:	1				
Depth:	0				
Sample Type:	Disturbed	Failure Photographs			
Description:	Gray sandy silt				
Test Type:	Direct Shear				
Remarks:					

OPC04.HSD

Direct Shear Test (ASTM D3080)

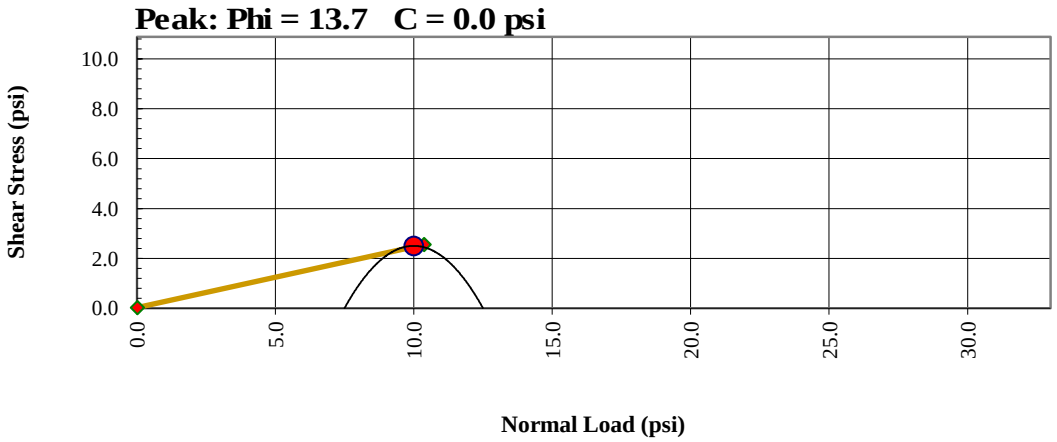
Date

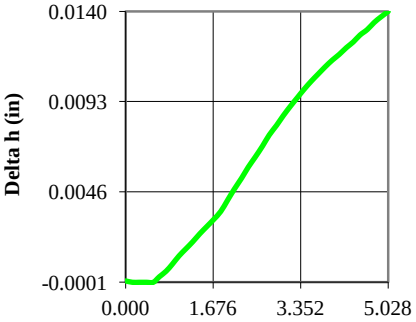
Checked By

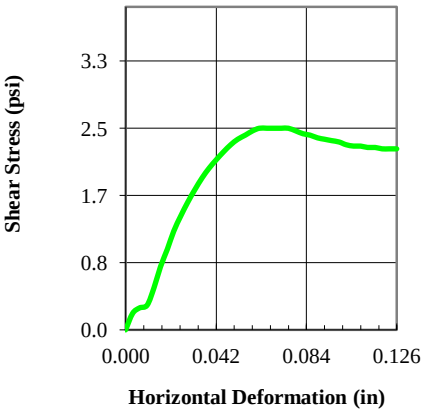
Date

Date

Tested By







Initial	Specimen A	B	C	D
Moisture (%)	30.09			
Density (pcf)	60.17			
Void Ratio	1.749			
Saturation (%)	45.58			
Diameter (in)	2.500			
Height (in)	1.000			

Final	A	B	C	D
Moisture (%)	58.29			
Density (pcf)	59.41			
Void Ratio	1.785			
Saturation (%)	87.15			
Diameter (in)	2.500			
Height (in)	0.996			
Normal Stress (psi)	10.0			
Peak Stress (psi)	2.5			
Residual Stress (psi)				
Strain (%)	3.019			
Rate (in/min)	0.02			

Project Date	
Date	8/13/14

Project:	Malone Superfund				
Location:	OPCO1				
Project Number:	1754	N/A	N/A	N/A	N/A
Boring Number					
Sample Number:	1				
Depth:					
Sample Type:	Disturbed	Failure Photographs			
Description:	Dark silty sand				
Test Type:	Direct Shear				
Remarks:					

Kenall Inc.
Geotechnical, Environmental & Material Engineers

Project No:	**1754**
Report Date:	**8/6/2014**
Report No:	**SPC03-i**

Permeability of Granular Soils (Constant Head)
(ASTM D2434)

Project No:	1754	Sample Identification:	SPC03
Technician:	MB	Sample Description:	Gray Silty Sand
Project:	**1754-Malone Superfund- Phase II**		

INITIAL CONDITIONS				FINAL CONDITIONS			
MOISTURE DATA		SPECIMEN DATA		MOISTURE DATA		SPECIMEN DATA	
Tare No.:	A	Length, in:	4.600	Tare No.:	1	Length, in:	4.600
Wet+Tare, gms:	46.70	Diameter, in:	3.975	Wet+Tare, gms:	56.7	Diameter, in:	3.975
Dry+Tare, gms:	36.66	Wet mass, gms:	1234.9	Dry+Tare, gms:	33.8	Wet mass, gms:	1408.9
Tare Weight, gms	15.13	Area, in^2:	12.4	Tare Weight, gms:	1.7	Area, in^2:	12.4
Moisture, %	46.6	Volume, in^3	57.1	Moisture, %	71.1	Volume, in^3	57.1
		Unit wet wt, pcf:	82.2			Unit wet wt, pcf:	93.8
Specific Gravity:	2.65	Unit dry wt, pcf:	56.1	Specific Gravity:	2.65	Unit dry wt, pcf:	54.8
head, in:	5	Void Ratio:	1.949	head, in:	5	Void Ratio:	2.016
		Reservoir tube dia	0.629				

PERMEABILITY MEASUREMENTS

Date	h	Area for Q	Q (cm^3)	Time (sec)	Q/At (cm/sec)	H/L	Temp (˚C)	α	Permeability K (cm/sec)	Permeability K_{20} (cm/sec)
8/5/2014	0.10	56.75	5.675236	30	2.36E-03	1.1	22	0.953	2.17E-03	2.07E-03
8/5/2014	0.10	56.75	5.675236	30	2.36E-03	1.1	22	0.953	2.17E-03	2.07E-03
8/5/2014	0.20	56.75	11.35047	30	4.73E-03	1.1	22	0.953	4.35E-03	4.14E-03
8/5/2014	0.10	56.75	5.675236	30	2.36E-03	1.1	22	0.953	2.17E-03	2.07E-03
8/5/2014	0.60	56.75	34.05142	180	2.36E-03	1.1	22	0.953	2.17E-03	2.07E-03
8/5/2014	1.00	56.75	56.75236	300	2.36E-03	1.1	22	0.953	2.17E-03	2.07E-03
8/5/2014	1.00	56.75	56.75236	300	2.36E-03	1.1	22	0.953	2.17E-03	2.07E-03
8/5/2014	1.00	56.75	56.75236	300	2.36E-03	1.1	22	0.953	2.17E-03	2.07E-03
8/5/2014	1.00	56.75	56.75236	300	2.36E-03	1.1	22	0.953	2.17E-03	2.07E-03
8/5/2014	0.90	56.75	51.07713	300	2.13E-03	1.1	22	0.953	1.96E-03	1.86E-03
8/5/2014	1.00	56.75	56.75236	300	2.36E-03	1.1	22	0.953	2.17E-03	2.07E-03
8/5/2014	0.90	56.75	51.07713	300	2.13E-03	1.1	22	0.953	1.96E-03	1.86E-03
8/5/2014	1.00	56.75	56.75236	300	2.36E-03	1.1	22	0.953	2.17E-03	2.07E-03
8/5/2014	0.90	56.75	51.07713	300	2.13E-03	1.1	22	0.953	1.96E-03	1.86E-03
8/5/2014	0.80	56.75	45.40189	300	1.89E-03	1.1	22	0.953	1.74E-03	1.66E-03
8/5/2014	2.00	56.75	113.5047	300	4.73E-03	1.1	22	0.953	4.35E-03	4.14E-03
8/5/2014	2.60	56.75	147.5561	1200	1.54E-03	1.1	22	0.953	1.41E-03	1.35E-03
8/5/2014	2.80	56.75	158.9066	900	2.21E-03	1.1	22	0.953	2.03E-03	1.93E-03

Coefficient of Permeability, k = **2.31E-03** cm/sec
Coefficient of Permeability, k_{20} = **2.20E-03** cm/sec

*Assumed specific gravity

Kenall Inc.
Geotechnical, Environmental & Material Engineers

Project No:	**1754**
Report Date:	**8/6/2014**
Report No:	**SPC04-i**

Permeability of Granular Soils (Constant Head)
(ASTM D2434)

Project No:	1754	Sample Identification:	SPC04
Technician:	MB	Sample Description:	Gray Sandy Silt
Project:	**Living Earth Lab Testing**		

INITIAL CONDITIONS				FINAL CONDITIONS			
MOISTURE DATA		SPECIMEN DATA		MOISTURE DATA		SPECIMEN DATA	
Tare No.:	A	Length, in:	4.600	Tare No.:	1	Length, in:	4.600
Wet+Tare, gms:	51.12	Diameter, in:	3.975	Wet+Tare, gms:	64.9	Diameter, in:	3.975
Dry+Tare, gms:	41.29	Wet mass, gms:	1218.6	Dry+Tare, gms:	42.4	Wet mass, gms:	1303.4
Tare Weight, gms	15.47	Area, in^2:	12.4	Tare Weight, gms:	1.7	Area, in^2:	12.4
Moisture, %	38.1	Volume, in^3	57.1	Moisture, %	55.4	Volume, in^3	57.1
		Unit wet wt, pcf:	81.2			Unit wet wt, pcf:	86.8
Specific Gravity:	2.65	Unit dry wt, pcf:	58.8	Specific Gravity:	2.65	Unit dry wt, pcf:	55.9
head, in:	5	Void Ratio:	1.813	head, in:	5	Void Ratio:	1.960
		Reservoir tube dia	0.629				

PERMEABILITY MEASUREMENTS

Date	h	Area for Q	Q (cm^3)	Time (sec)	Q/At (cm/sec)	H/L	Temp (˚C)	α	Permeability K (cm/sec)	Permeability K_{20} (cm/sec)
8/5/2014	0.40	56.75	22.70095	60	4.73E-03	1.1	22	0.953	4.35E-03	4.14E-03
8/5/2014	0.50	56.75	28.37618	120	2.95E-03	1.1	22	0.953	2.72E-03	2.59E-03
8/5/2014	0.60	56.75	34.05142	120	3.54E-03	1.1	22	0.953	3.26E-03	3.11E-03
8/5/2014	1.40	56.75	79.45331	300	3.31E-03	1.1	22	0.953	3.04E-03	2.90E-03
8/5/2014	1.40	56.75	79.45331	300	3.31E-03	1.1	22	0.953	3.04E-03	2.90E-03
8/5/2014	1.30	56.75	73.77807	300	3.07E-03	1.1	22	0.953	2.83E-03	2.69E-03
8/5/2014	1.40	56.75	79.45331	300	3.31E-03	1.1	22	0.953	3.04E-03	2.90E-03
8/5/2014	1.30	56.75	73.77807	300	3.07E-03	1.1	22	0.953	2.83E-03	2.69E-03
8/5/2014	1.30	56.75	73.77807	300	3.07E-03	1.1	23	0.953	2.83E-03	2.69E-03
8/5/2014	1.30	56.75	73.77807	300	3.07E-03	1.1	24	0.953	2.83E-03	2.69E-03
8/5/2014	1.30	56.75	73.77807	300	3.07E-03	1.1	25	0.953	2.83E-03	2.69E-03
8/5/2014	1.20	56.75	68.10284	300	2.84E-03	1.1	26	0.953	2.61E-03	2.49E-03

Coefficient of Permeability, k =	**2.90E-03**	cm/sec
Coefficient of Permeability, k_{20} =	**2.76E-03**	cm/sec

*Assumed specific gravity

Kenall Inc.
Geotechnical, Environmental & Material Engineers

Project No:	**1754**
Report Date:	**8/6/2014**
Report No:	**OPC01-i**

Permeability of Granular Soils (Constant Head)
(ASTM D2434)

Project No:	1754	Sample Identification:	OPC01
Technician:	MB	Sample Description:	Olive gray Silty Sand
Project:	**Living Earth Lab Testing**		

INITIAL CONDITIONS				FINAL CONDITIONS			
MOISTURE DATA		SPECIMEN DATA		MOISTURE DATA		SPECIMEN DATA	
Tare No.:	A	Length, in:	4.600	Tare No.:	1	Length, in:	4.600
Wet+Tare, gms:	71.10	Diameter, in:	3.975	Wet+Tare, gms:	66.4	Diameter, in:	3.975
Dry+Tare, gms:	55.78	Wet mass, gms:	1155.3	Dry+Tare, gms:	40.6	Wet mass, gms:	1320.0
Tare Weight, gms	1.73	Area, in^2:	12.4	Tare Weight, gms:	1.7	Area, in^2:	12.4
Moisture, %	28.3	Volume, in^3	57.1	Moisture, %	66.1	Volume, in^3	57.1
		Unit wet wt, pcf:	76.9			Unit wet wt, pcf:	87.9
Specific Gravity:	2.65	Unit dry wt, pcf:	59.9	Specific Gravity:	2.65	Unit dry wt, pcf:	52.9
head, in:	5	Void Ratio:	1.758	head, in:	5	Void Ratio:	2.125
		Reservoir tube dia	0.629				

PERMEABILITY MEASUREMENTS

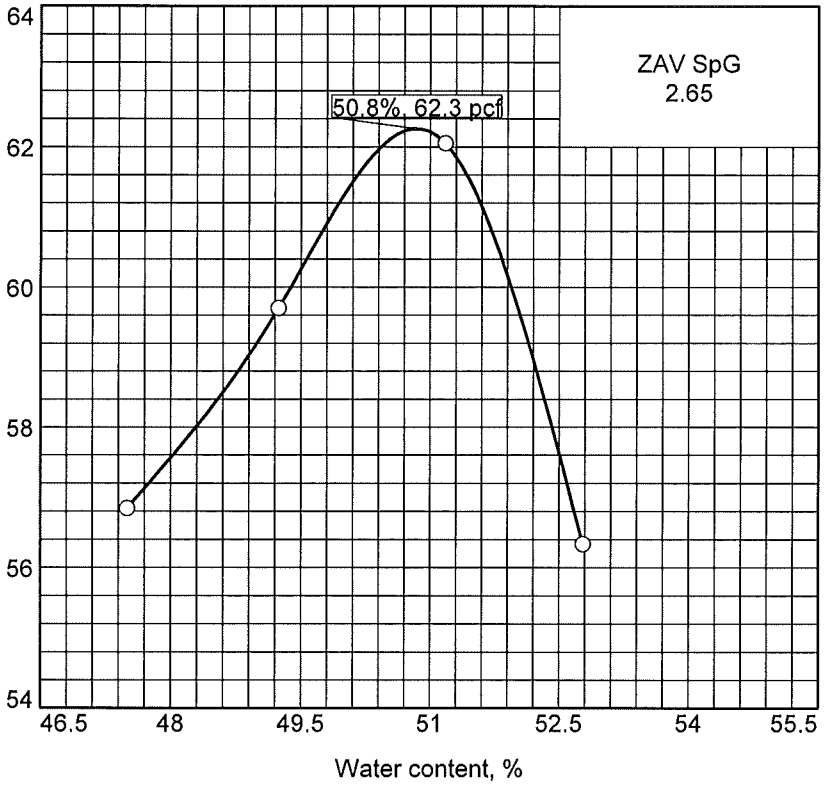
Date	h	Area for Q	Q (cm^3)	Time (sec)	Q/At (cm/sec)	H/L	Temp (°C)	α	Permeability K (cm/sec)	Permeability K_{20} (cm/sec)
8/7/2014	2.00	56.75	113.5047	30	4.73E-02	1.1	22	0.953	5.14E-02	4.90E-02
8/7/2014	1.60	56.75	90.80378	30	3.78E-02	1.1	22	0.953	4.11E-02	3.92E-02
8/7/2014	1.50	56.75	85.12855	30	3.54E-02	1.1	22	0.953	3.85E-02	3.67E-02
8/7/2014	1.60	56.75	90.80378	30	3.78E-02	1.1	22	0.953	4.11E-02	3.92E-02
8/7/2014	1.70	56.75	96.47902	30	4.02E-02	1.1	22	0.953	4.37E-02	4.16E-02
8/7/2014	1.90	56.75	107.8295	30	4.49E-02	1.1	22	0.953	4.88E-02	4.65E-02
8/7/2014	1.10	56.75	62.4276	30	2.60E-02	1.1	22	0.953	2.83E-02	2.69E-02
8/7/2014	1.40	56.75	79.45331	30	3.31E-02	1.1	22	0.953	3.60E-02	3.43E-02
8/7/2014	1.60	56.75	90.80378	30	3.78E-02	1.1	22	0.953	4.11E-02	3.92E-02
8/7/2014	1.40	56.75	79.45331	30	3.31E-02	1.1	22	0.953	3.60E-02	3.43E-02
8/7/2014	3.00	56.75	170.2571	60	3.54E-02	1.1	22	0.953	3.85E-02	3.67E-02
8/7/2014	2.70	56.75	153.2314	60	3.19E-02	1.1	22	0.953	3.47E-02	3.31E-02
8/7/2014	3.00	56.75	170.2571	60	3.54E-02	1.1	22	0.953	3.85E-02	3.67E-02
8/7/2014	2.90	56.75	164.5819	60	3.43E-02	1.1	22	0.953	3.72E-02	3.55E-02
8/7/2014	7.70	56.75	436.9932	180	3.03E-02	1.1	22	0.953	3.30E-02	3.14E-02
8/7/2014	5.80	56.75	329.1637	120	3.43E-02	1.1	22	0.953	3.72E-02	3.55E-02

Coefficient of Permeability, k = **3.82E-02** cm/sec
Coefficient of Permeability, k_{20} = **3.65E-02** cm/sec

*Assumed specific gravity

This report contains test results of randomly selected material. Engineering properties may differ during the day's construction activity. The report shall not be altered or r

COMPACTION TEST REPORT



Curve No.

Test Specification:
ASTM D 698-00a Method A Standard

Preparation Method Dry
Hammer Wt. 5.5 lb.
Hammer Drop 12 in.
Number of Layers three
Blows per Layer 25
Mold Size 0.03333 cu. ft.
Test Performed on Material Passing #4 **Sieve**

NM 47 **LL** 49 **PI** 5
Sp.G. (ASTM D 854) 2.65
%>#4 0 **%<No.200** 18.5
USCS SM **AASHTO**
Date Sampled 7/16/14
Date Tested 7/21/14
Tested By Igonibo george

TESTING DATA

	1	2	3	4	5	6
WM + WS	3279.9	3359.3	3430.5	3313.5		
WM	2012.3	2012.3	2012.3	2012.3		
WW + T #1	640.2	614.9	638.8	625.9		
WD + T #1	552.8	533.9	549.5	534.7		
TARE #1	368.8	369.4	375.0	361.9		
WW + T #2						
WD + T #2						
TARE #2						
MOISTURE	47.5	49.2	51.2	52.8		
DRY DENSITY	56.8	59.7	62.1	56.3		

TEST RESULTS

Maximum dry density = 62.3 pcf

Optimum moisture = 50.8 %

Material Description

Olive gray silty sand

Project No. 1754 **Client:** Entact, LLC
Project: 1754 G&C Malone Superfund Site E7888

○ **Source of Sample:** SPC03 **Sample Number:** 1

Remarks:
Test methods: ASTM D4318, D2216, D114, D854/Assumed specific gravity

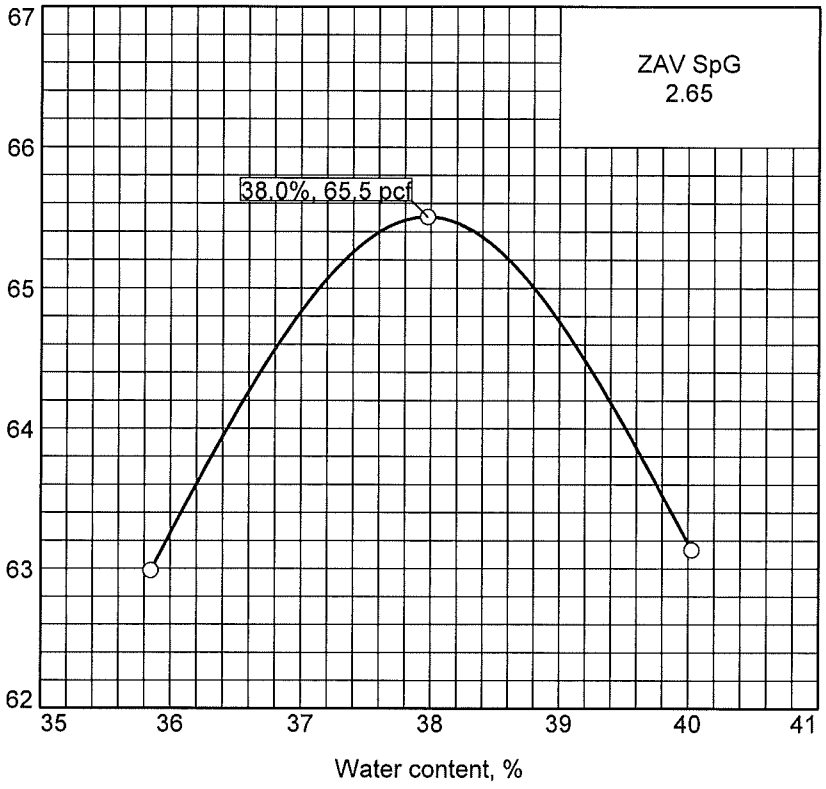
Checked by:
Title:

Kleinfelder

Figure

This report contains test results of randomly selected material. Engineering properties may differ during the day's construction activity. The report shall not be altered or r

COMPACTION TEST REPORT



Curve No.

Test Specification:
ASTM D 698-00a Method A Standard

Preparation Method	Dry
Hammer Wt.	5.5 lb.
Hammer Drop	12 in.
Number of Layers	three
Blows per Layer	25
Mold Size	0.03333 cu. ft.

Test Performed on Material Passing #4 **Sieve**

NM 38 **LL** 48 **PI** 7
Sp.G. (ASTM D 854) 2.65
%>#4 0 **%<No.200** 76.6
USCS ML **AASHTO** -
Date Sampled 7/16/14
Date Tested 7/22/14
Tested By Igonibo george

TESTING DATA

	1	2	3	4	5	6
WM + WS	3305.9	3378.7	3348.8			
WM	2012.3	2012.3	2012.3			
WW + T #1	608.7	607.3	672.3			
WD + T #1	544.1	533.1	588.8			
TARE #1	363.9	337.7	380.2			
WW + T #2						
WD + T #2						
TARE #2						
MOISTURE	35.8	38.0	40.0			
DRY DENSITY	63.0	65.5	63.1			

TEST RESULTS

Maximum dry density = 65.5 pcf

Optimum moisture = 38.0 %

Material Description

Gray sandy silt

Project No. 1754 **Client:** Entact, LLC
Project: 1754 G&C Malone Superfund Site E7888

○ **Source of Sample:** SPC04 **Sample Number:** 1

Remarks:
Test methods: ASTM D4318, D2216, D1140, ASTM D854/Assumed specific gravity

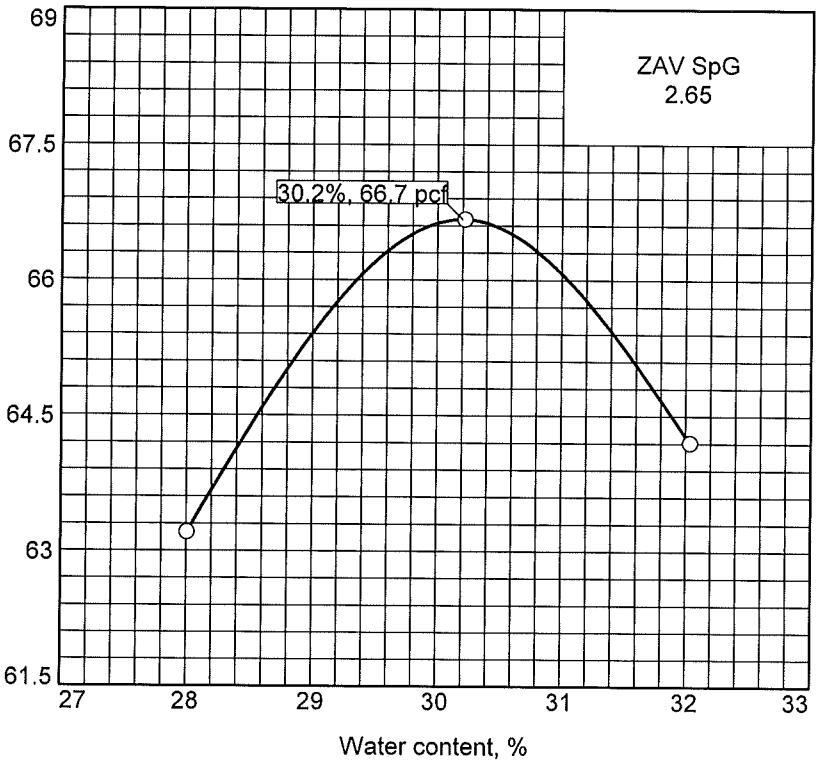
Checked by: Kris D Prasad
Title:

Konell Inc

Figure

This report contains test results of randomly selected material. Engineering properties may differ during the day's construction activity. The report shall not be altered or r

COMPACTION TEST REPORT



Curve No.

Test Specification:
ASTM D 698-00a Method A Standard

Preparation Method Dry
Hammer Wt. 5.5 lb.
Hammer Drop 12 in.
Number of Layers three
Blows per Layer 25
Mold Size 0.03333 cu. ft.
Test Performed on Material Passing #4 **Sieve**

NM 30.25 **LL** NP **PI** NP
Sp.G. (ASTM D 854) 2.65
%>#4 0 **%<No.200** 35.4
USCS SM **AASHTO** -
Date Sampled 7/16/14
Date Tested 7/22/14
Tested By Igonibo george

TESTING DATA

	1	2	3	4	5	6
WM + WS	3235.5	3324.8	3293.9			
WM	2012.3	2012.3	2012.3			
WW + T #1	622.2	606.6	611.0			
WD + T #1	567.9	555.5	548.5			
TARE #1	374.0	386.4	353.4			
WW + T #2						
WD + T #2						
TARE #2						
MOISTURE	28.0	30.2	32.0			
DRY DENSITY	63.2	66.7	64.2			

TEST RESULTS

Maximum dry density = 66.7 pcf

Optimum moisture = 30.2 %

Material Description

Dark gray silty sand

Project No. 1754 **Client:** Entact, LLC
Project: 1754 G&C Malone Superfund Site E7888

○ **Source of Sample:** OPC01 **Sample Number:** 1

Remarks:
Test methods: ASTM D4318, D2216, D1140, ASTM D854/Assumed specific gravity

Checked by: Kris D. Prasad
Title:

Kenell Inc.

Figure

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

APPENDIX 3

Veneer Slope Stability Analysis

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

VENEER SLOPE STABILITY
MALONE SERVICE COMPANY SUPERFUND SITE

A3-1 INTRODUCTION

A3-1.1 Purpose

The purpose of this calculation package is to present the veneer slope stability analysis of the liner system and final cover system of the Malone Service Company Superfund Site (site). The liner system will be constructed on the base of the landfill and on side slopes of the levee (slope varies) and berm (3 horizontal to 1 vertical (3H:1V)). Since liner system stability represents an interim condition for the period of time between the liner system installation and waste placement against the liner system, the target minimum calculated factor of safety is 1.25. The final cover system will be constructed with varying slopes (steepest portion will be 7H:1V) on top of the landfill. Since final cover system stability represents a long-term condition, the target minimum calculated factor of safety is 1.5.

For cases of large-displacement veneer stability considered herein, the target minimum calculated factor of safety using large-displacement soil shear strengths is 1.0 for interim conditions (liner system) and 1.15 for final conditions (final cover system). The approach taken is to back-calculate the minimum peak and large displacement secant effective-stress friction angle for the liner system and final cover system interfaces for a specified height of overburden material placed on the liner or final cover system and for a selected target factor of safety. The overburden height was selected to be 10 feet vertically. It should be recognized that if larger interface shear strengths are measured for the site-specific products/materials, then a greater allowable protective cover height could be calculated.

A3-1.2 Method

An analysis of veneer slope stability considers noncircular wedge-type potential slip surfaces that extend along a liner system or final cover system. The critical interface for a liner system or cover system that incorporates geosynthetics typically occurs along an interface between a geosynthetic and an adjacent geosynthetic or soil.

The finite slope factor of safety equation, as formulated by Giroud et al. (1995), is:

$$FS = \left[\frac{\gamma_t(t-t_w)+\gamma_b t_w}{\gamma_t(t-t_w)+\gamma_{sat}t_w}\right]\frac{tan\delta}{tan\beta} + \\ + \frac{a/sin\beta}{\gamma_t(t-t_w)+\gamma_{sat}t_w} + \\ + \left[\frac{\gamma_t(t-t_w^*)+\gamma_b t_w^*}{\gamma_t(t-t_w)+\gamma_{sat}t_w}\right]\left[\frac{tan\varphi/(2sin\beta cos^2\beta)}{1-tan\beta tan\varphi}\right]\frac{t}{h} + \\ + \left[\frac{1}{\gamma_t(t-t_w)+\gamma_{sat}t_w}\right]\left[\frac{1/(sin\beta cos\beta)}{1-tan\beta tan\varphi}\right]\frac{ct}{h}$$

where: FS = factor of safety;
δ = interface friction angle;
a = apparent interface adhesion;
ϕ = soil internal friction angle;
c = apparent soil cohesion;
γ_t = moist soil unit weight;
γ_b = buoyant soil unit weight;
γ_{sat} = saturated soil unit weight;
t = depth of cover soil above critical interface;
t_w = water depth above critical interface on the sidewall;
t^*_w = water depth at slope toe;
β = sidewall slope angle; and
h = vertical height of slope.

It should be noted that while the above equation specifically applies to an interface above a geomembrane or similar liquid barrier layer, it could also be applied to interfaces below the geomembrane by changing the coefficient of the first term to 1.0 (i.e., the coefficient of tanδ / tanβ to 1.0).

The finite slope method is used herein to evaluate the factor of safety for veneer slope stability of the liner system and final cover system for the site.

It is assumed that the geocomposite drainage layer in the liner system and the geocomposite drainage layer in the final cover system have sufficient hydraulic capacity to convey all liquid percolating into them, and that the peak heads in the drainage layers are less than the thickness of the layers (i.e., $t_w \leq 0.2$ in. at the geotextile/geomembrane or geocomposite/geomembrane interface). This value of t_w is very small and has negligible impact on the calculated slope

stability factor of safety. Thus, the assumption of $t_w = 0$ can be used in the above equation. It is further assumed that leachate collected in the drainage layer at the toe of the liner system side slope will be allowed to outlet without the buildup of excessive hydraulic head at the slope toe (i.e., $t^*_w \leq 0.2$ in.). For the final cover system, it is assumed that drainage layer outlets at the toe of the side slope will be maintained to preclude the buildup of excessive hydraulic head at the slope toe (i.e., $t^*_w \leq 0.2$ in.). With $t_w = 0$ and $t^*_w \approx 0$, the finite slope equation simplifies to:

$$FS = \frac{tan\delta}{tan\beta} + \frac{a/sin\beta}{\gamma_t t} + \left[\frac{tan\varphi/(2sin\beta cos^2\beta)}{1 - tan\beta tan\varphi}\right]\frac{t}{h} + \left[\frac{1}{\gamma_t t}\right]\left[\frac{1/(sin\beta cos\beta)}{1 - tan\beta tan\varphi}\right]\frac{ct}{h}$$

Also, the landfill facility incorporates a landfill gas vent system. Therefore, it is considered reasonable to assume that gas pressures beneath the final cover system are negligible.

A3-2 CRITICAL CROSS SECTIONS

The critical cases for veneer stability occur along the longest and steepest slopes. The top of soil subgrade grading plan, shown on Figure 2 in the main slope stability report, incorporates 3 horizontal to 1 vertical (3H:1V) side slopes. As previously mentioned, the protective cover height will be limited to 10 ft vertical placement increments.

The top of final cover grading plan, shown on Figure 3 in the main slope stability report, has a maximum of 7H:1V side slopes. The 7H:1V slope reaches a maximum height of approximately 10 ft at the highest point on the landfill cover (i.e., landfill top deck elevation of 24 ft above mean sea level (ft, MSL) vs. final cover elevation of 14 ft, MSL at the lowest point of the limit of waste).

A3-3 LINER SYSTEM AND FINAL COVER SYSTEM MATERIALS

A3-3.1 Liner System on Side Slopes

The liner system for the Malone Service Company site consists of the following components, from top to bottom:

- 1-foot (ft.) thick protective cover soil layer (impacted soils);
- double-sided geocomposite drainage layer;
- textured 80-mil HDPE geomembrane;
- double-sided geocomposite;
- textured 80-mil HDPE geomembrane;
- geosynthetic clay liner (GCL); and
- 1-ft thick compacted clay.

A3-3.2 Final Cover System on Side Slopes

The final cover system cross section consists of the following components from top to bottom:

- grassy vegetation;
- 6-inch (in.) thick vegetative layer;
- 1-ft thick cover soil layer;
- geocomposite drainage layer (single- or double-sided);
- 40-mil LLDPE geomembrane (smooth or textured);
- geosynthetic clay liner (GCL); and
- double sided geocomposite (gas vent layer).

A3-4 MATERIAL PROPERTIES

The liner system and final cover system material parameters were described in the main narrative of the Slope Stability Analysis. In summary, the following material parameters were selected for the veneer stability analyses:

Material	γ	Drained Strength		Undrained Strength	
	pcf	c' (psf)	ϕ'	c (psf)	ϕ
Final Cover Soils	120	250	20	1000	0
Liner Protective Cover	120	250	15	750	0
Liner and cover interface	-	$\delta_{interface}$ (back-calculated from analysis)			

A3-5 RESULTS

A3-5.1 Liner System (Drained Conditions)

Calculated factors of safety for both short term and long term stability of the liner system are presented at the end of this report. The long term stability (drained condition) is more critical and is presented below. The parameters used in this analysis are:

$\beta = 18.4°$ (3H:1V slope), $\gamma = 120$ pcf, $a = 0$, $c' = 750$, $\varphi' = 0°$, $t = 1$ ft, and $h = 10$ ft.

Solving for peak interface friction angle

$$1.25 \leq \frac{tan\delta}{\tan(18.4)} + \left[\frac{\tan(15)/(2\sin(18.4)cos^2(18.4))}{1 - tan(18.4)tan(15)}\right]\frac{1}{10} + \left[\frac{1}{120 * 1}\right]\left[\frac{1/(sin(18.4)cos(18.4))}{1 - tan(18.4)tan(15)}\right]\frac{250 * 1}{10}$$

Solving the above equation for $FS_{target} \leq 1.25$ (i.e. a target minimum calculated factor of safety of 1.25), $\delta_{peak} = 8.3°$ and $FS_{calculated} = 1.25$.

Solving for large displacement interface friction angle

$$1.0 \leq \frac{tan\delta}{\tan(18.4)} + \left[\frac{\tan(15)/(2\sin(18.4)cos^2(18.4))}{1 - tan(18.4)tan(15)}\right]\frac{1}{10} + \left[\frac{1}{120 * 1}\right]\left[\frac{1/(sin(18.4)cos(18.4))}{1 - tan(18.4)tan(15)}\right]\frac{250 * 1}{10}$$

Solving the above equation for $FS_{target} \leq 1.0$ (i.e. a target minimum calculated factor of safety of 1.0), $\delta_{large\ displacement} = 3.6°$ and $FS_{calculated} = 1.0$.

A3-5.2 Final Cover System

Calculated factors of safety for both short term and long term stability of the final cover system are presented at the end of this report. The long term stability (drained condition) is more critical and is presented below. The parameters used in this analysis are:

$\beta = 8.1°$ (7H:1V slope), $\gamma = 120$ pcf, a = 0, c' = 250, $\varphi' = 20°$, t = 1.5 ft, and h = 10 ft.

Solving for peak and large displacement interface friction angles

$$1.5 = \frac{tan\delta}{\tan(8.1)} + \left[\frac{\tan(20)/(2sin(8.1)cos^2(8.1))}{1 - tan(8.1)tan(20)}\right]\frac{1.5}{10} + \left[\frac{1}{120 * 1.5}\right]\left[\frac{1/(sin(8.1)cos(8.1))}{1 - tan(8.1)tan(20)}\right]\frac{250 * 1.5}{10}$$

Solving the above equation for $FS_{target} \leq 1.5$ (i.e. a target minimum calculated factor of safety of 1.5), $\delta_{peak} = \delta_{large\ displacement} = 0°$ and $FS_{calculated} = 1.8$. It is noted that these back-calculated friction angles of zero degrees are due to the overlying cover soil having enough strength to maintain slope stability.

A3-6 CONCLUSIONS

For the analyses herein, Geosyntec selected target calculated factors of safety of 1.25 for the interim conditions (liner system) and 1.5 for the final conditions (final cover system) when calculating peak interface friction angles, and factors of safety of 1.0 for the interim conditions (liner system) and 1.15 for the final conditions (final cover system) when using large-displacement interface friction angles.

The veneer stability calculation tables are presented at the end of this appendix and the results have been incorporated into Table 6 of the main Slope Stability Analysis report.

The interfaces that could potentially have the most critical interface friction angle are the ones that incorporate a geomembrane (i.e., geotextile/geomembrane, geonet/geomembrane, or geomembrane/GCL). Product specific interface friction angles need to be assessed prior to installation. Site-specific interface testing is recommended prior to construction of the liner system and final cover system. The results of the tests need to exceed the minimum back-calculated interface friction angles in order to meet the target factor of safety. The maximum

incremental height that overburden soil can be placed against the liner or final cover system will be limited to a vertical height of 10 ft in order to achieve the target calculated factors of safety.

A3-7 REFERENCES

Giroud, J.P., Bachus, R.C., and Bonaparte, R. (1995). "Influence of Water Flow on the Stability of Geosynthetic-Soil Layered Systems on Slopes", *Geosynthetics International*, Vol. 2, No. 6, pp. 1149-1180.

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Results of Veneer Stability Analysis

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Liner System (Berm Slope: 30 feet at 3:1)

Input Parameters			Factor of Safety Calculation				
Drained Strength of Cover Soil	c' (psf)	250					
	ϕ' (deg)	15					
	ϕ' (rad)	0.26					
Undrained Strength of Cover Soil	c (psf)	750		Peak Strengths		Large Displacement Strengths	
	φ (deg)	0		Undrained Peak	Drained Peak	Undrained Large Disp	Drained Large Disp
	φ (rad)	0.00	Term 1	0.438	0.438	0.189	0.189
Thickness and Unit Weight	Unit Weight γ_t (pcf)	120	Term 2	0.000	0.052	0.000	0.052
	Thickness t (ft)	1	Term 3	2.083	0.763	2.083	0.763
Slope Geometry	Slope Height h (ft)	10	Calculated FS	**2.521**	**1.252**	**2.272**	**1.003**
	Slope Angle β (deg)	18.4	Target FS	**1.25**	**1.25**	**1.00**	**1.00**
	Slope Angle β (rad)	0.32	OK?	OK	OK	OK	OK
Geocomposite Interface Strength	δ_{peak} (deg)	8.3	Factor of Safety Calculation				
	$\delta_{large\ disp}$ (deg)	3.6					
	δ_{peak} (rad)	0.14					
	$\delta_{large\ disp}$ (rad)	0.06					

Final Cover System (70 feet at 7:1)

Input Parameters			Factor of Safety Calculation				
Drained Strength of Cover Soil	c' (psf)	250					
	ϕ' (deg)	20					
	ϕ' (rad)	0.35					
Undrained Strength of Cover Soil	c (psf)	1000		Peak Strengths		Large Displacement Strengths	
	φ (deg)	0		Undrained Peak	Drained Peak	Undrained Large Disp	Drained Large Disp
	φ (rad)	0.00	Term 1	0.000	0.000	0.000	0.000
Thickness and Unit Weight	Unit Weight (pcf)	120	Term 2	0.000	0.208	0.000	0.208
	Thickness (ft)	1.5	Term 3	5.952	1.570	5.952	1.570
Slope Geometry	Slope Height (ft)	10	Calculated FS	**5.952**	**1.777**	**5.952**	**1.777**
	Slope Angle β (deg)	8.1	Target FS	**1.50**	**1.50**	**1.15**	**1.15**
	Slope Angle β (rad)	0.14	OK?	OK	OK	OK	OK
Geocomposite Interface Strength	δ_{peak} (deg)	0.0	Factor of Safety Calculation				
	$\delta_{large\ disp}$ (deg)	0.0					
	δ_{peak} (rad)	0.0					
	$\delta_{large\ disp}$ (rad)	0.0					

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

APPENDIX 4

Results of SLIDE Slope Stability Analyses

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Run Number: 1

Project Summary

- File Name: 01 Section B Levee Undrained Circular.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:15:46 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Left to Right
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Circular
- Search Method: Auto Refine Search
- Divisions along slope: 12
- Circles per division: 12
- Number of iterations: 10
- Divisions to use in next iteration: 50%
- Composite Surfaces: Disabled
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill
Color							
Strength Type	Undrained	Undrained	Mohr-Coulomb	Undrained	Undrained	Undrained	Undrained
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120
Cohesion [psf]			0				
Friction Angle [deg]			25				
Cohesion Type	1525	760		1630	1535	1615	1000
Water Surface	None	None	Water Table	None	None	None	None

Hu Value			1				
Ru Value	0	0		0	0	0	0

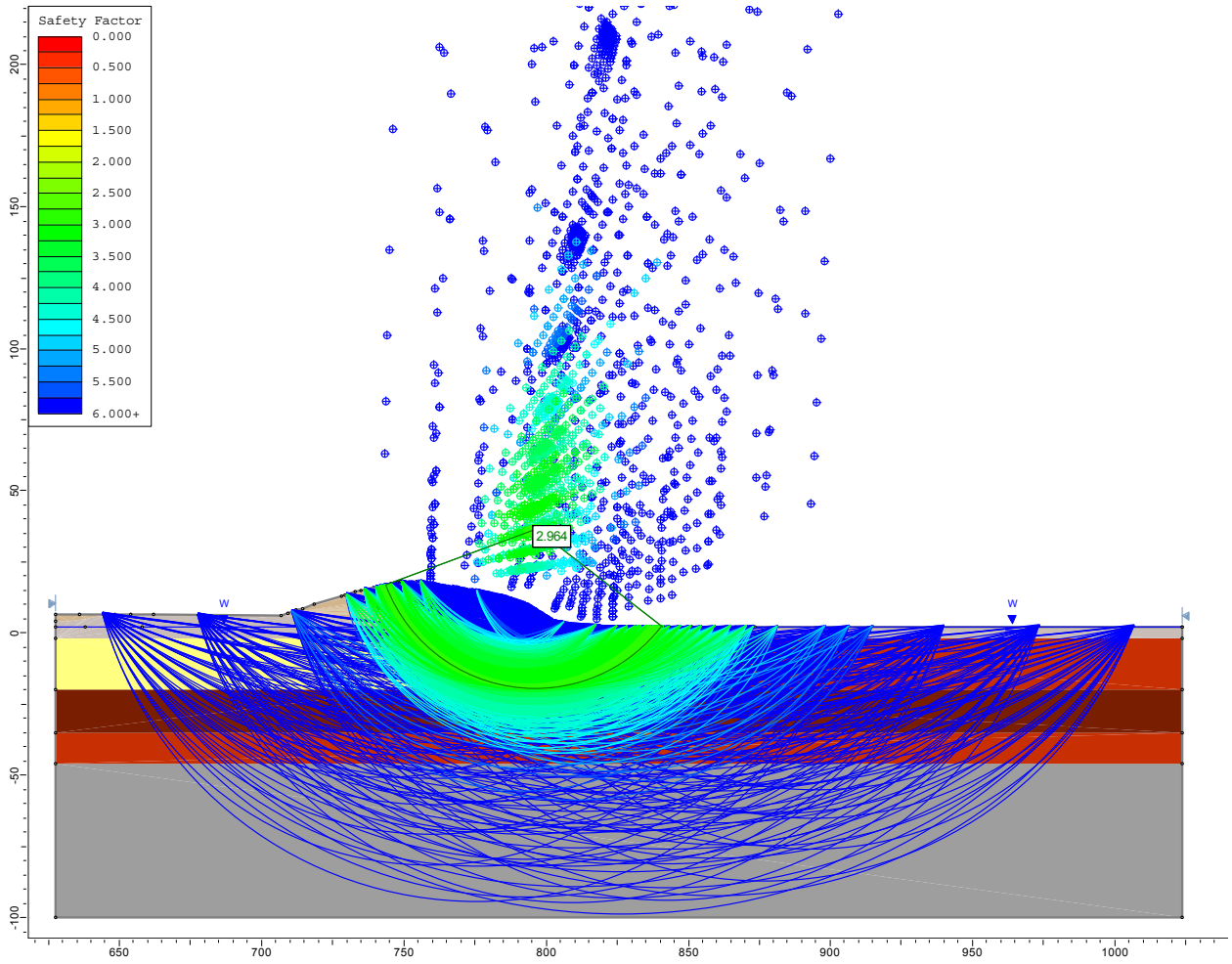
Global Minimums

Method: spencer

- FS: 2.963550
- Center: 796.335, 36.380
- Radius: 56.372
- Left Slip Surface Endpoint: 743.479, 16.781
- Right Slip Surface Endpoint: 841.008, 1.997
- Resisting Moment=6.19045e+006 lb-ft
- Driving Moment=2.08886e+006 lb-ft
- Resisting Horizontal Force=86065.7 lb
- Driving Horizontal Force=29041.4 lb
- Total Slice Area=2048.94 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Run Number: 2

Project Summary

- File Name: 02 Section B Levee Undrained Noncircular.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:15:46 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Left to Right
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Search Method: Auto Refine Search
- Divisions along slope: 12
- Circles per division: 12
- Number of iterations: 10
- Divisions to use in next iteration: 50%
- Number of vertices per surface: 12
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill
Color							
Strength Type	Undrained	Undrained	Mohr-Coulomb	Undrained	Undrained	Undrained	Undrained
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120
Cohesion [psf]			0				
Friction Angle [deg]			25				
Cohesion Type	1525	760		1630	1535	1615	1000
Water Surface	None	None	Water Table	None	None	None	None
Hu Value			1				

Ru Value	0	0	0	0	0	0

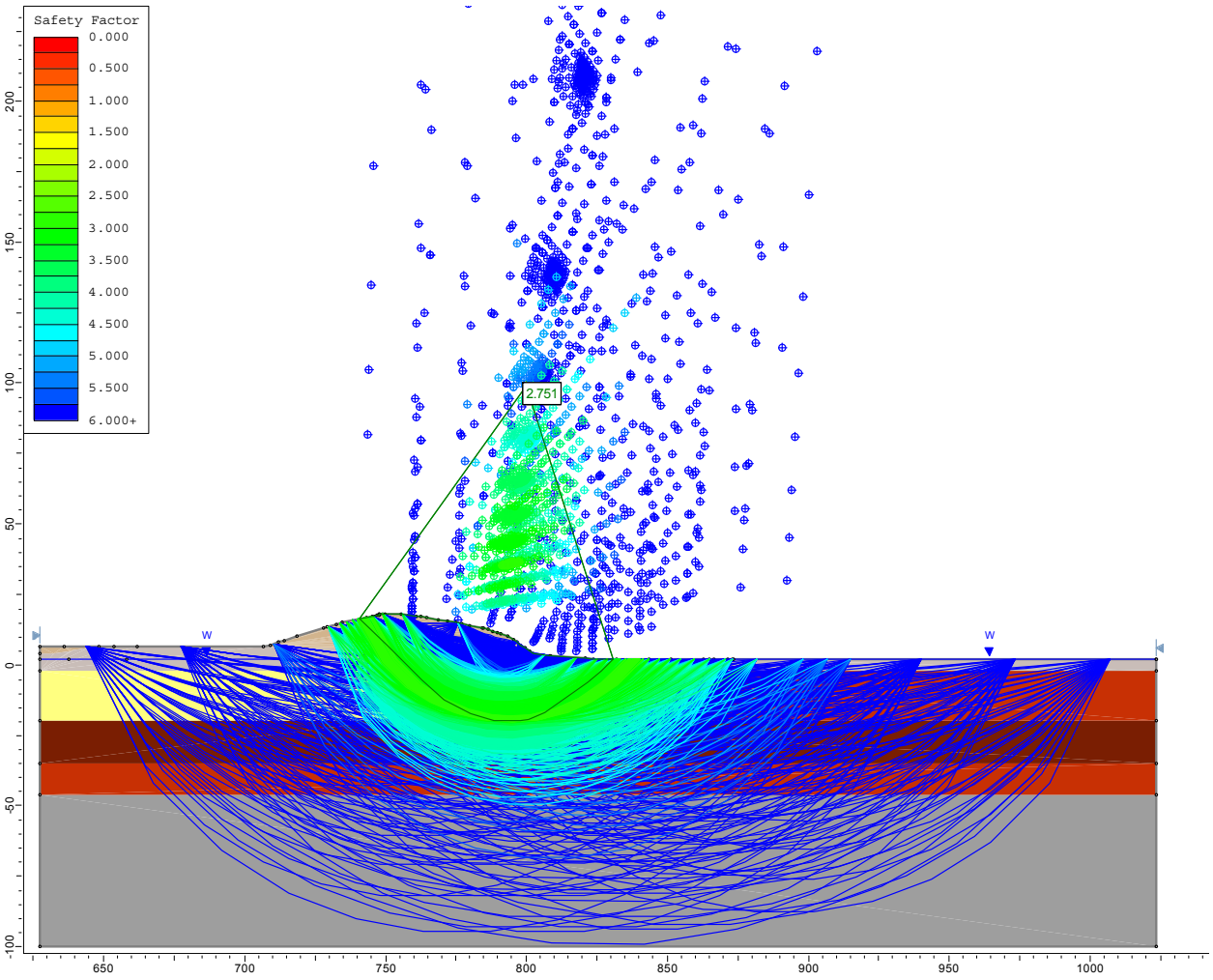
Global Minimums

Method: spencer

- FS: 2.750990
- Axis Location: 800.086, 99.023
- Left Slip Surface Endpoint: 740.881, 16.256
- Right Slip Surface Endpoint: 830.777, 1.999
- Resisting Moment=1.05928e+007 lb-ft
- Driving Moment=3.85055e+006 lb-ft
- Resisting Horizontal Force=81721.9 lb
- Driving Horizontal Force=29706.4 lb
- Total Slice Area=1749.27 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Run Number: 3

Project Summary

- File Name: 03 Section B Levee Drained Circular.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:15:46 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Left to Right
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Circular
- Search Method: Auto Refine Search
- Divisions along slope: 12
- Circles per division: 12
- Number of iterations: 10
- Divisions to use in next iteration: 50%
- Composite Surfaces: Disabled
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill
Color							
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120
Cohesion [psf]	430	575	0	430	575	430	250
Friction Angle [deg]	13.2	18.3	25	13.2	18.3	13.2	20
Water Surface	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table
Hu Value	1	1	1	1	1	1	1

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

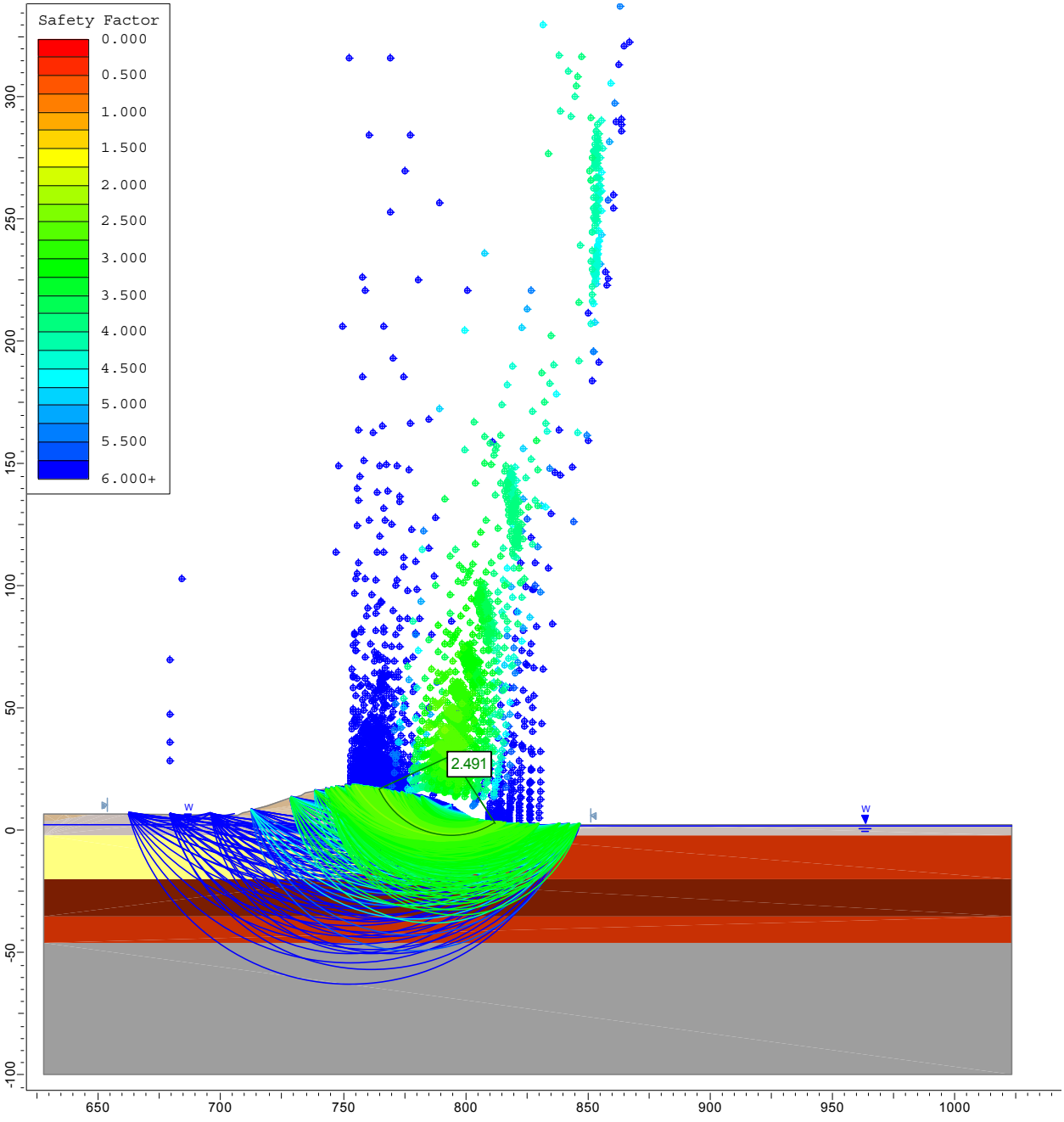
Global Minimums

Method: spencer

- FS: 2.491500
- Center: 794.466, 30.259
- Radius: 32.726
- Left Slip Surface Endpoint: 764.704, 16.653
- Right Slip Surface Endpoint: 812.215, 2.764
- Resisting Moment=1.03416e+006 lb-ft
- Driving Moment=415075 lb-ft
- Resisting Horizontal Force=27721.5 lb
- Driving Horizontal Force=11126.4 lb
- Total Slice Area=422.356 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 4

Project Summary

- File Name: 04 Section B Levee Drained Noncircular.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:15:46 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Left to Right
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Search Method: Auto Refine Search
- Divisions along slope: 12
- Circles per division: 12
- Number of iterations: 10
- Divisions to use in next iteration: 50%
- Number of vertices per surface: 12
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill
Color							
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120
Cohesion [psf]	430	575	0	430	575	430	250
Friction Angle [deg]	13.2	18.3	25	13.2	18.3	13.2	20
Water Surface	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table
Hu Value	1	1	1	1	1	1	1

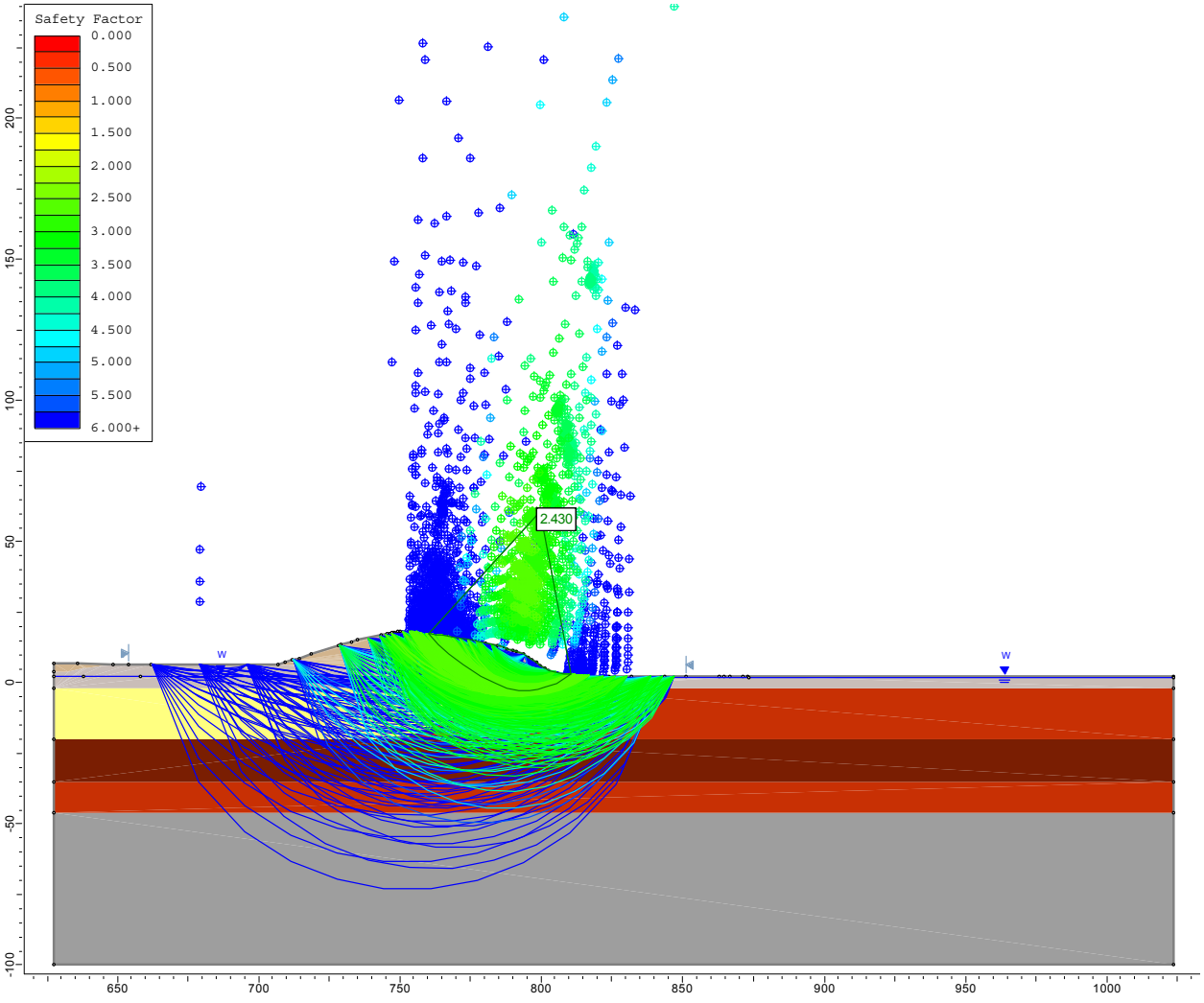
Global Minimums

Method: spencer

- FS: 2.429510
- Axis Location: 799.645, 60.663
- Left Slip Surface Endpoint: 759.899, 17.354
- Right Slip Surface Endpoint: 810.445, 2.881
- Resisting Moment=1.98046e+006 lb-ft
- Driving Moment=815169 lb-ft
- Resisting Horizontal Force=28863.1 lb
- Driving Horizontal Force=11880.3 lb
- Total Slice Area=437.861 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 5

Project Summary

- File Name: 05 Section B Berm Undrained Circular.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:15:46 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Circular
- Search Method: Auto Refine Search
- Divisions along slope: 12
- Circles per division: 12
- Number of iterations: 10
- Divisions to use in next iteration: 50%
- Composite Surfaces: Disabled
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill
Color							
Strength Type	Undrained	Undrained	Mohr-Coulomb	Undrained	Undrained	Undrained	Undrained
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120
Cohesion [psf]			0				
Friction Angle [deg]			25				
Cohesion Type	1525	760		1630	1535	1615	1000
Water Surface	None	None	Water Table	None	None	None	None

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Hu Value			1				
Ru Value	0	0		0	0	0	0

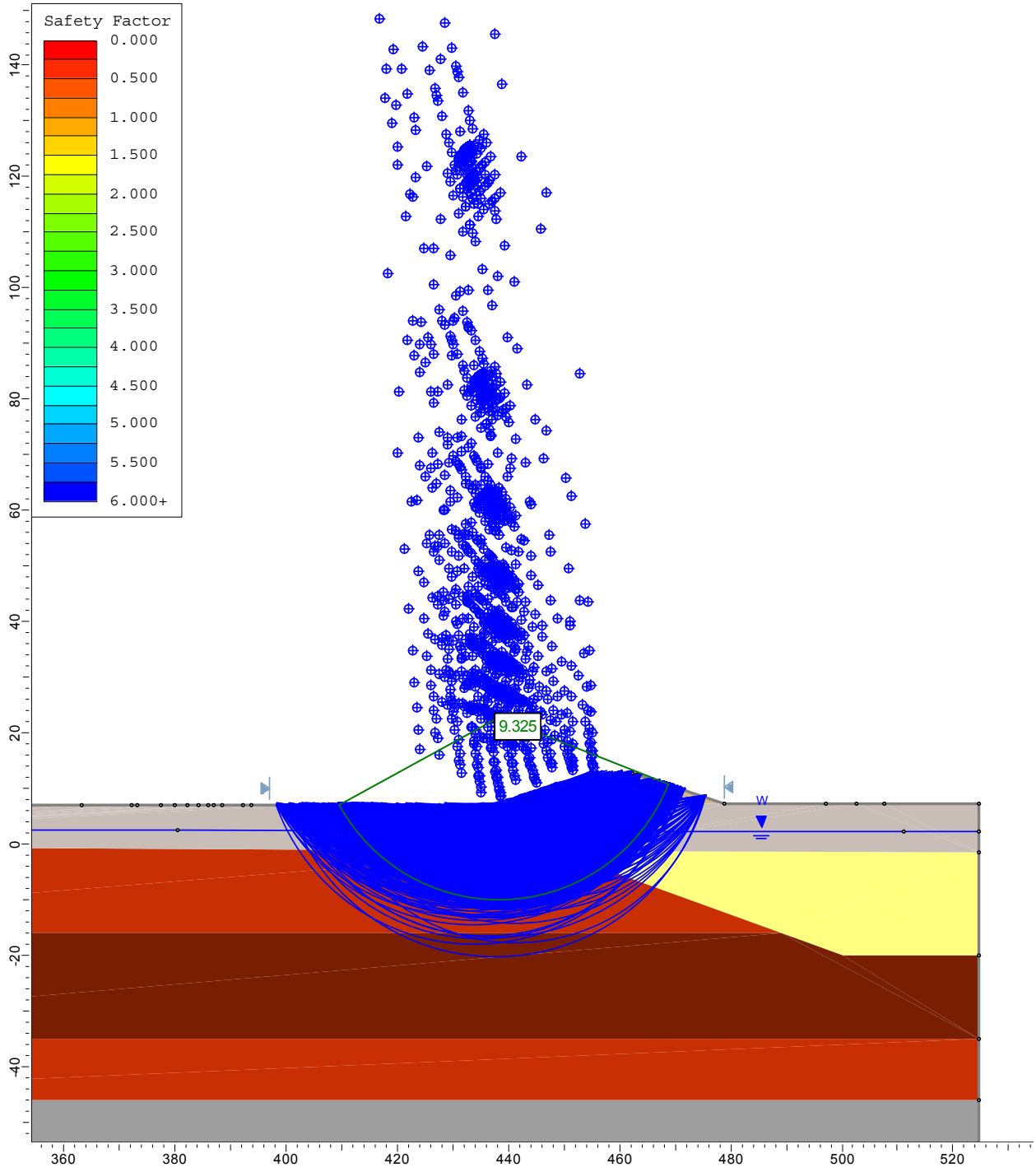
Global Minimums

Method: spencer

- FS: 9.325290
- Center: 438.337, 22.751
- Radius: 32.932
- Left Slip Surface Endpoint: 409.415, 7.000
- Right Slip Surface Endpoint: 468.949, 10.610
- Resisting Moment=2.41802e+006 lb-ft
- Driving Moment=259297 lb-ft
- Resisting Horizontal Force=55203.2 lb
- Driving Horizontal Force=5919.73 lb
- Total Slice Area=825.315 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 6

Project Summary

- File Name: 06 Section B Berm Undrained Noncircular through Stratum II.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:15:46 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 100
- Left Projection Angle (End Angle): 130
- Right Projection Angle (Start Angle): 30
- Right Projection Angle (End Angle): 80
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill
Color							
Strength Type	Undrained	Undrained	Mohr-Coulomb	Undrained	Undrained	Undrained	Undrained
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120
Cohesion [psf]			0				
Friction Angle [deg]			25				
Cohesion Type	1525	760		1630	1535	1615	1000
Water	None	None	Water Table	None	None	None	None

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Surface							
Hu Value			1				
Ru Value	0	0		0	0	0	0

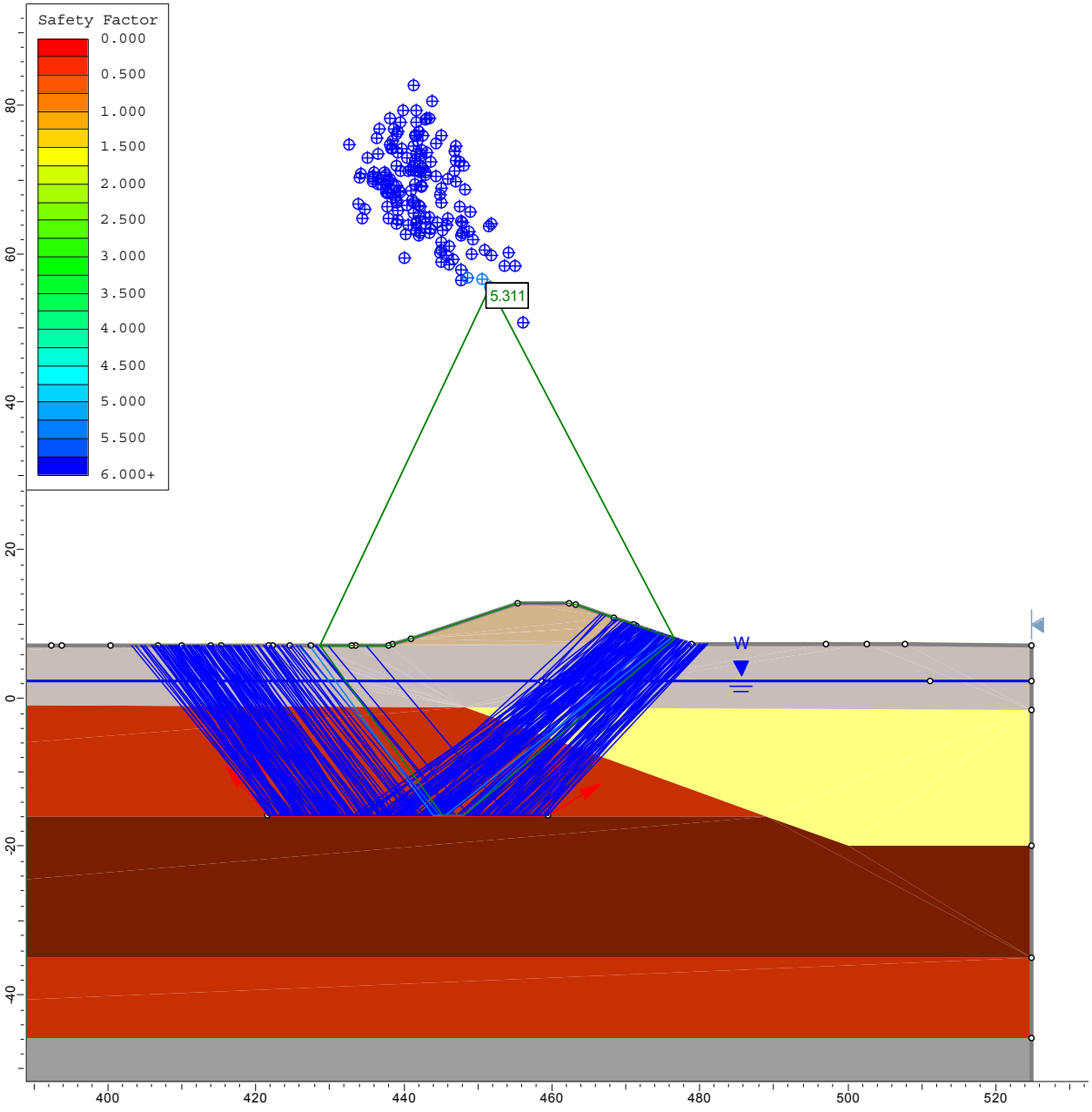
Global Minimums

Method: spencer

- FS: 5.311150
- Axis Location: 451.619, 55.437
- Left Slip Surface Endpoint: 428.719, 7.005
- Right Slip Surface Endpoint: 476.625, 8.058
- Resisting Moment=3.5602e+006 lb-ft
- Driving Moment=670326 lb-ft
- Resisting Horizontal Force=48944.3 lb
- Driving Horizontal Force=9215.39 lb
- Total Slice Area=709.328 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 7

Project Summary

- File Name: 07 Section B Berm Drained Circular.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:15:46 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Circular
- Search Method: Auto Refine Search
- Divisions along slope: 12
- Circles per division: 12
- Number of iterations: 10
- Divisions to use in next iteration: 50%
- Composite Surfaces: Disabled
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill
Color							
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120
Cohesion [psf]	430	575	0	430	575	430	250
Friction Angle [deg]	13.2	18.3	25	13.2	18.3	13.2	20
Water Surface	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table
Hu Value	1	1	1	1	1	1	1

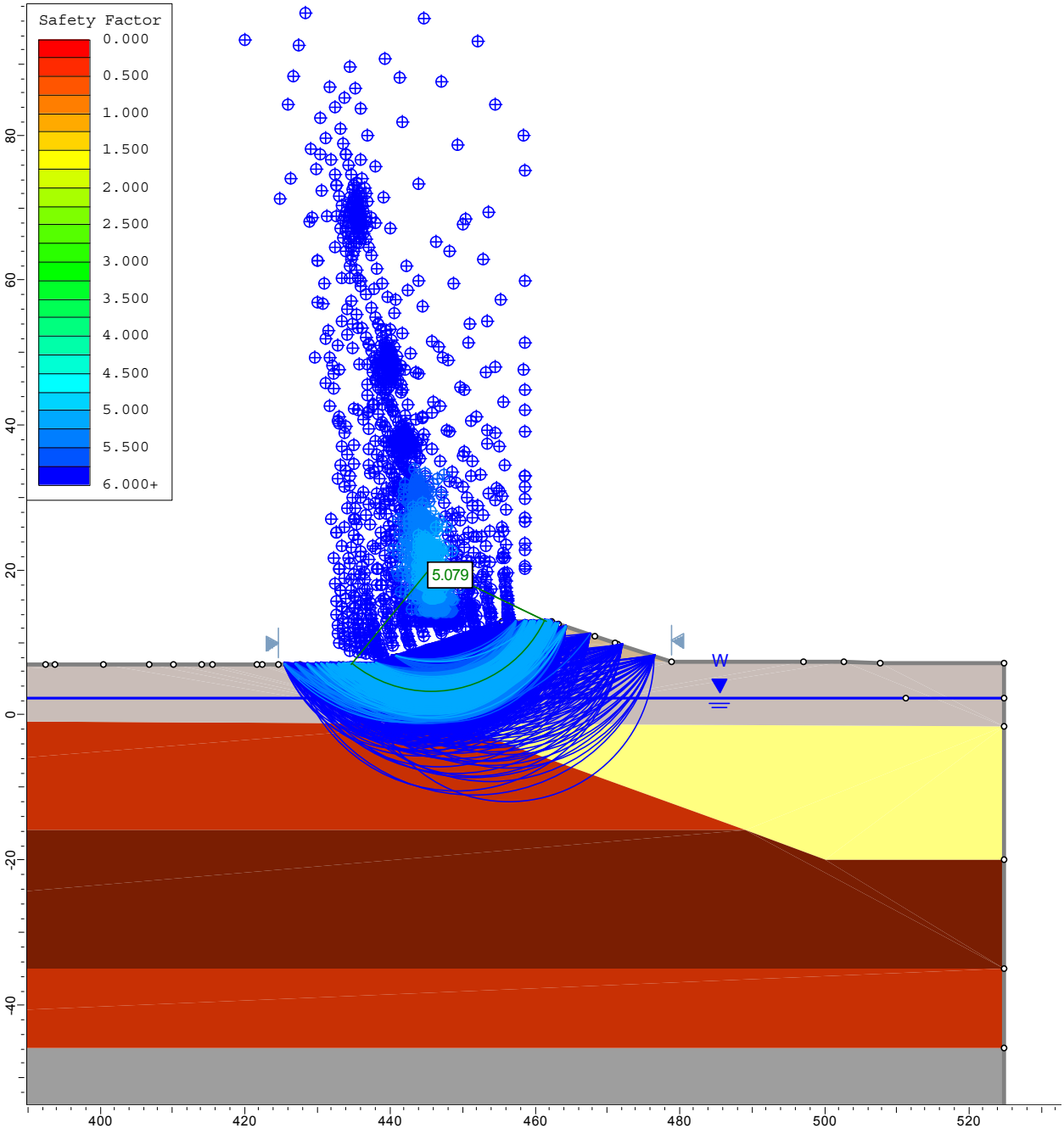
Global Minimums

Method: spencer

- FS: 5.078990
- Center: 445.776, 20.468
- Radius: 17.461
- Left Slip Surface Endpoint: 434.655, 7.006
- Right Slip Surface Endpoint: 461.481, 12.838
- Resisting Moment=291747 lb-ft
- Driving Moment=57441.9 lb-ft
- Resisting Horizontal Force=14725.9 lb
- Driving Horizontal Force=2899.37 lb
- Total Slice Area=135.791 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 8

Project Summary

- File Name: 08 Section B Berm Drained Noncircular through Berm.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:15:46 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 100
- Left Projection Angle (End Angle): 130
- Right Projection Angle (Start Angle): 30
- Right Projection Angle (End Angle): 80
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill	Waste - Sludge
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120	90
Cohesion [psf]	430	575	0	430	575	430	250	0
Friction Angle [deg]	13.2	18.3	25	13.2	18.3	13.2	20	5
Water	Water	Water	Water Table	Water	Water	Water	Water Table	Water

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Surface	Table	Table		Table	Table	Table		Table
Hu Value	1	1	1	1	1	1	1	1

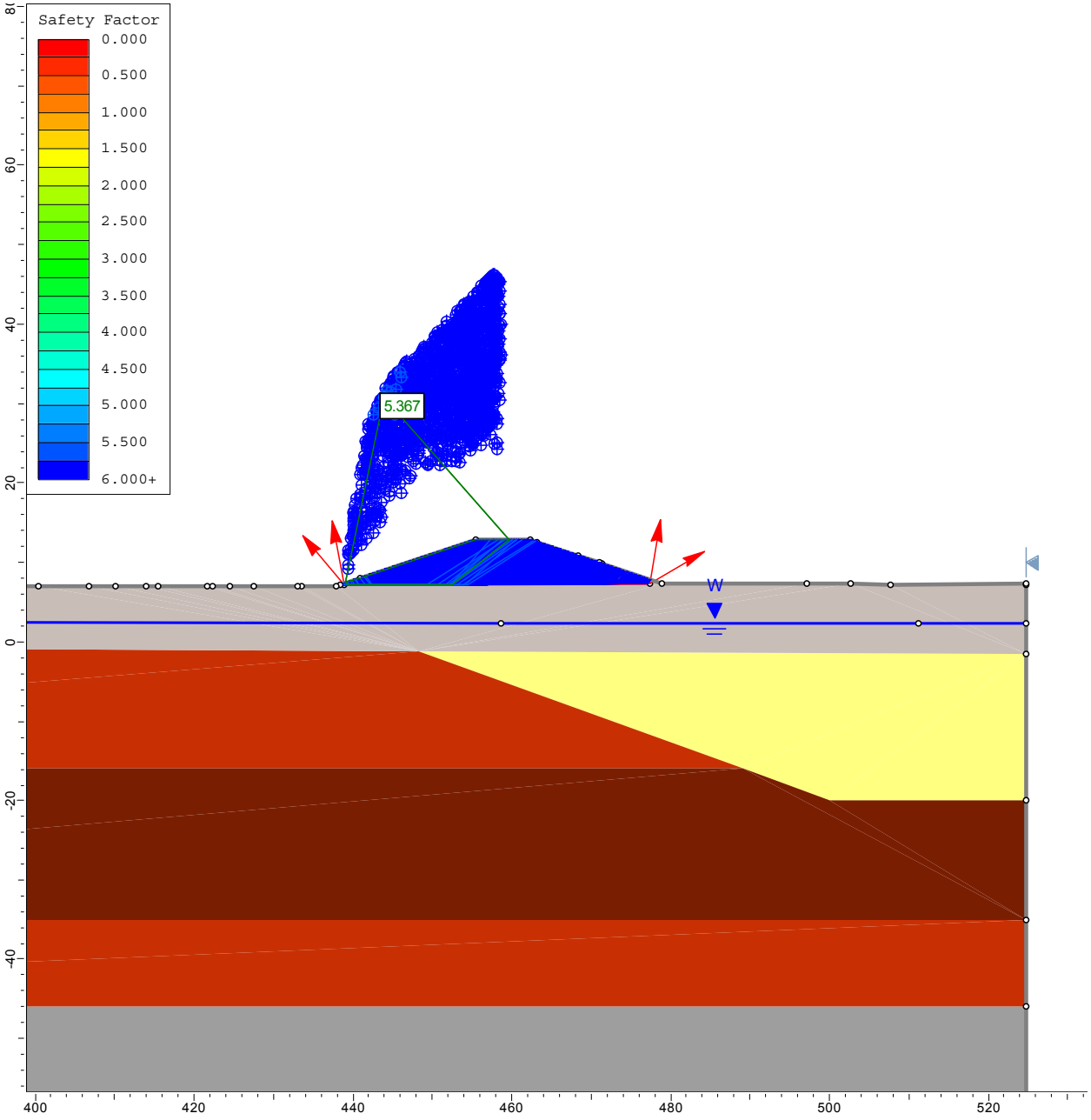
Global Minimums

Method: spencer

- FS: 5.366710
- Axis Location: 443.914, 30.768
- Left Slip Surface Endpoint: 439.033, 7.393
- Right Slip Surface Endpoint: 459.685, 12.838
- Resisting Moment=190070 lb-ft
- Driving Moment=35416.5 lb-ft
- Resisting Horizontal Force=7331.14 lb
- Driving Horizontal Force=1366.04 lb
- Total Slice Area=52.5262 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 9

Project Summary

- File Name: 09 Section A Interim Phase 1 Undrained Circular.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:12:40 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Left to Right
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Circular
- Search Method: Auto Refine Search
- Divisions along slope: 12
- Circles per division: 12
- Number of iterations: 10
- Divisions to use in next iteration: 50%
- Composite Surfaces: Disabled
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill	Cover
Color								
Strength Type	Undrained	Undrained	Mohr-Coulomb	Undrained	Undrained	Undrained	Undrained	Undrained
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120	120
Cohesion [psf]			0					
Friction Angle [deg]			25					
Cohesio	1525	760		1630	1535	1615	1000	1000

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

n Type								
Water Surface	None	None	Water Table	None	None	None	None	None
Hu Value			1					
Ru Value	0	0		0	0	0	0	0

Property	Waste - Sludge	Liner	Waste - Impacted Soil
Color			
Strength Type	Mohr-Coulomb	Undrained	Undrained
Unit Weight [lbs/ft3]	90	120	120
Cohesion [psf]	0		
Friction Angle [deg]	5		
Cohesion Type		750	750
Water Surface	Water Table	None	None
Hu Value	1		
Ru Value		0	0

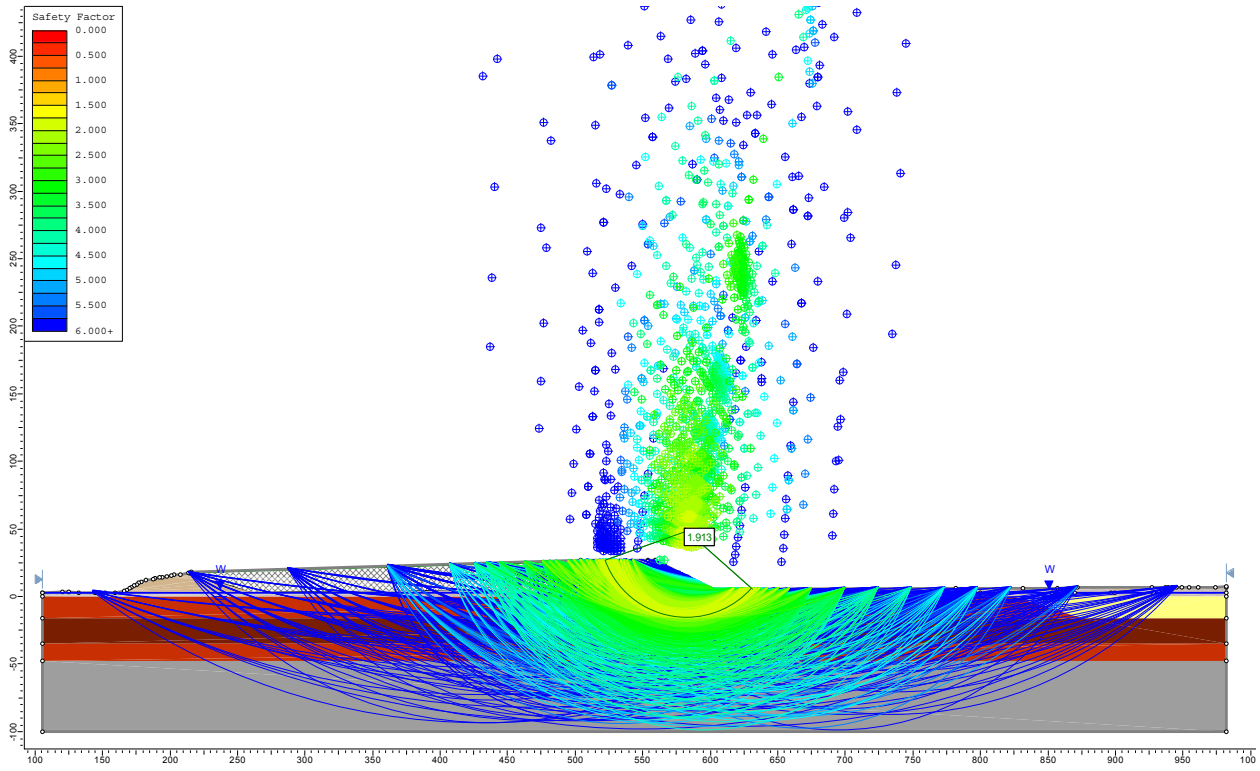
Global Minimums

Method: spencer

- FS: 1.913400
- Center: 582.959, 48.581
- Radius: 64.641
- Left Slip Surface Endpoint: 522.117, 26.750
- Right Slip Surface Endpoint: 631.127, 5.472
- Resisting Moment=6.58534e+006 lb-ft
- Driving Moment=3.44169e+006 lb-ft
- Resisting Horizontal Force=85750 lb
- Driving Horizontal Force=44815.5 lb
- Total Slice Area=2546.62 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 10

Project Summary

- File Name: 10 Section A Interim Phase 1 Undrained Noncircular through Liner.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:12:40 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Left to Right
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 135
- Left Projection Angle (End Angle): 135
- Right Projection Angle (Start Angle): 45
- Right Projection Angle (End Angle): 45
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill	Cover
Color								
Strength Type	Undrained	Undrained	Mohr-Coulomb	Undrained	Undrained	Undrained	Undrained	Undrained
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120	120
Cohesion [psf]			0					
Friction Angle [deg]			25					

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Cohesion Type	1525	760		1630	1535	1615	1000	1000
Water Surface	None	None	Water Table	None	None	None	None	None
Hu Value			1					
Ru Value	0	0		0	0	0	0	0

Property	Waste - Sludge	Liner	Waste - Impacted Soil
Color			
Strength Type	Mohr-Coulomb	Undrained	Undrained
Unit Weight [lbs/ft3]	90	120	120
Cohesion [psf]	0		
Friction Angle [deg]	5		
Cohesion Type		750	750
Water Surface	Water Table	None	None
Hu Value	1		
Ru Value		0	0

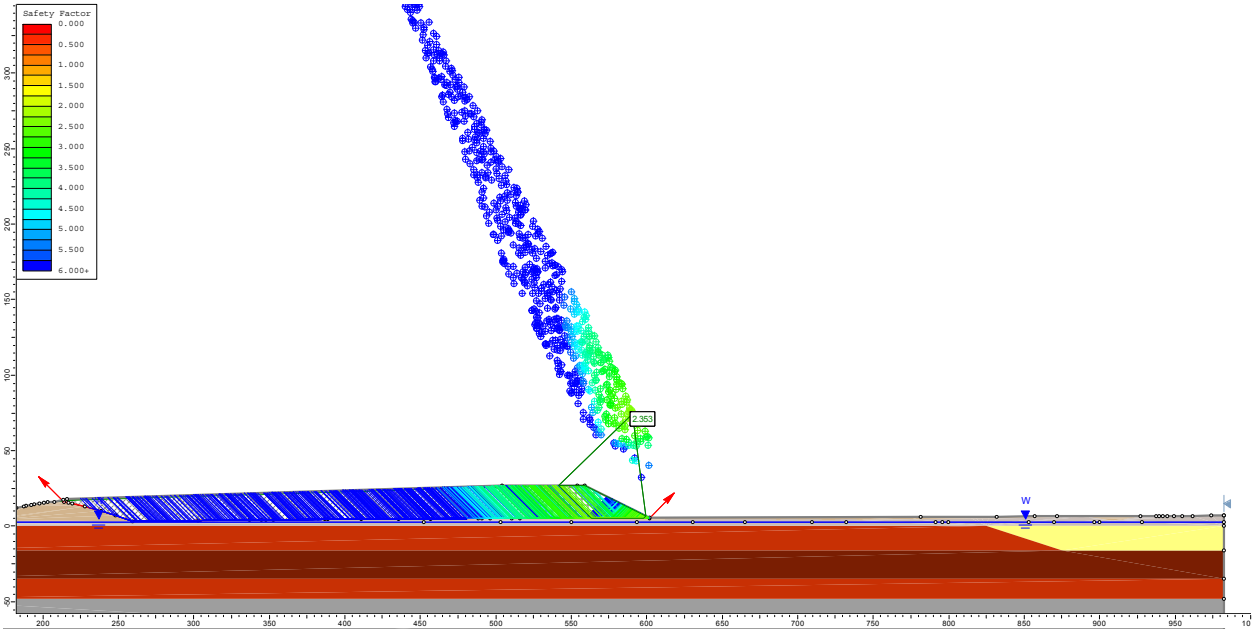
Global Minimums

Method: spencer

- FS: 2.353270
- Axis Location: 590.591, 74.075
- Left Slip Surface Endpoint: 541.790, 26.750
- Right Slip Surface Endpoint: 599.170, 6.639
- Resisting Moment=3.15513e+006 lb-ft
- Driving Moment=1.34074e+006 lb-ft
- Resisting Horizontal Force=40403.2 lb
- Driving Horizontal Force=17169 lb
- Total Slice Area=598.49 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 11

Project Summary

- File Name: 11 Section A Interim Phase 1 Drained Circular.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:12:40 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Left to Right
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Circular
- Search Method: Auto Refine Search
- Divisions along slope: 12
- Circles per division: 12
- Number of iterations: 10
- Divisions to use in next iteration: 50%
- Composite Surfaces: Disabled
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill	Cover
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120	120
Cohesion [psf]	430	575	0	430	575	430	250	250
Friction Angle [deg]	13.2	18.3	25	13.2	18.3	13.2	20	20
Water Surface	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Hu Value	1	1	1	1	1	1	1	1

Property	Waste - Sludge	Liner	Waste - Impacted Soil
Color			
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	90	120	120
Cohesion [psf]	0	250	450
Friction Angle [deg]	5	15	15
Water Surface	Water Table	Water Table	Water Table
Hu Value	1	1	1

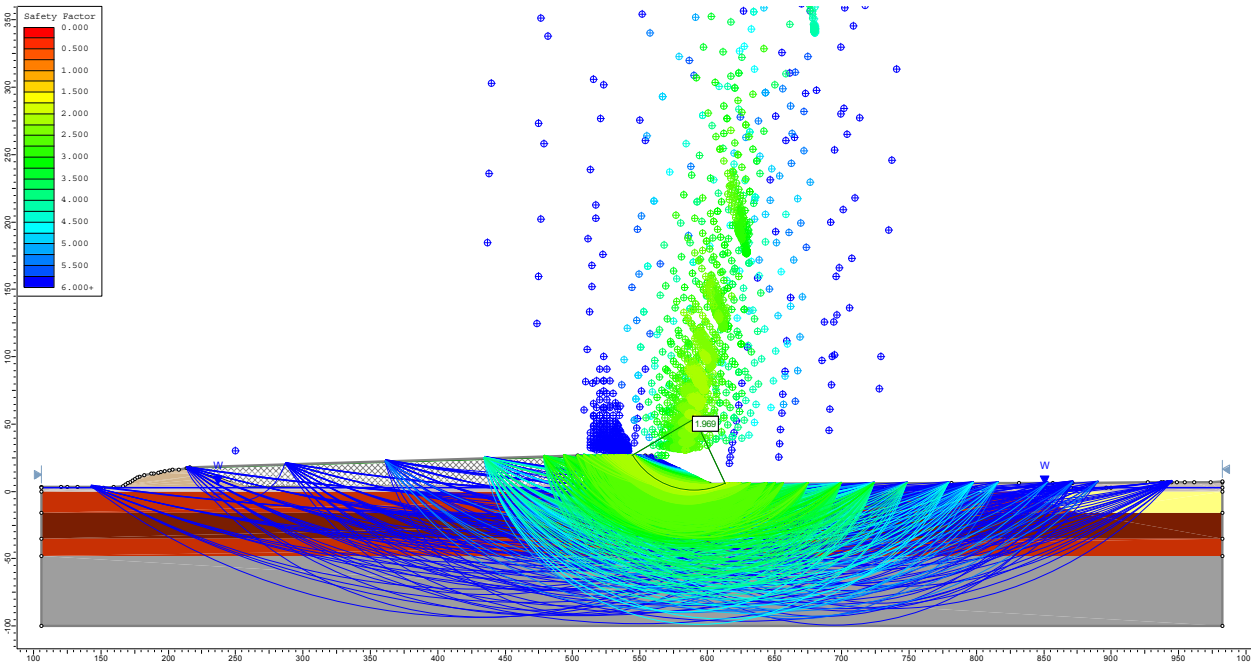
Global Minimums

Method: spencer

- FS: 1.969200
- Center: 590.641, 53.940
- Radius: 53.759
- Left Slip Surface Endpoint: 544.265, 26.750
- Right Slip Surface Endpoint: 613.747, 5.400
- Resisting Moment=2.87677e+006 lb-ft
- Driving Moment=1.46088e+006 lb-ft
- Resisting Horizontal Force=47843.5 lb
- Driving Horizontal Force=24295.9 lb
- Total Slice Area=731.52 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 12

Project Summary

- File Name: 12 Section A Interim Phase 1 Drained Noncircular through Liner.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:12:40 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Left to Right
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 135
- Left Projection Angle (End Angle): 135
- Right Projection Angle (Start Angle): 45
- Right Projection Angle (End Angle): 45
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill	Cover
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120	120
Cohesion [psf]	430	575	0	430	575	430	250	250
Friction Angle [deg]	13.2	18.3	25	13.2	18.3	13.2	20	20
Water	Water	Water	Water Table	Water	Water	Water	Water Table	Water

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Surface	Table	Table		Table	Table	Table		Table
Hu Value	1	1	1	1	1	1	1	1

Property	Waste - Sludge	Liner	Waste - Impacted Soil
Color			
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	90	120	120
Cohesion [psf]	0	250	450
Friction Angle [deg]	5	15	15
Water Surface	Water Table	Water Table	Water Table
Hu Value	1	1	1

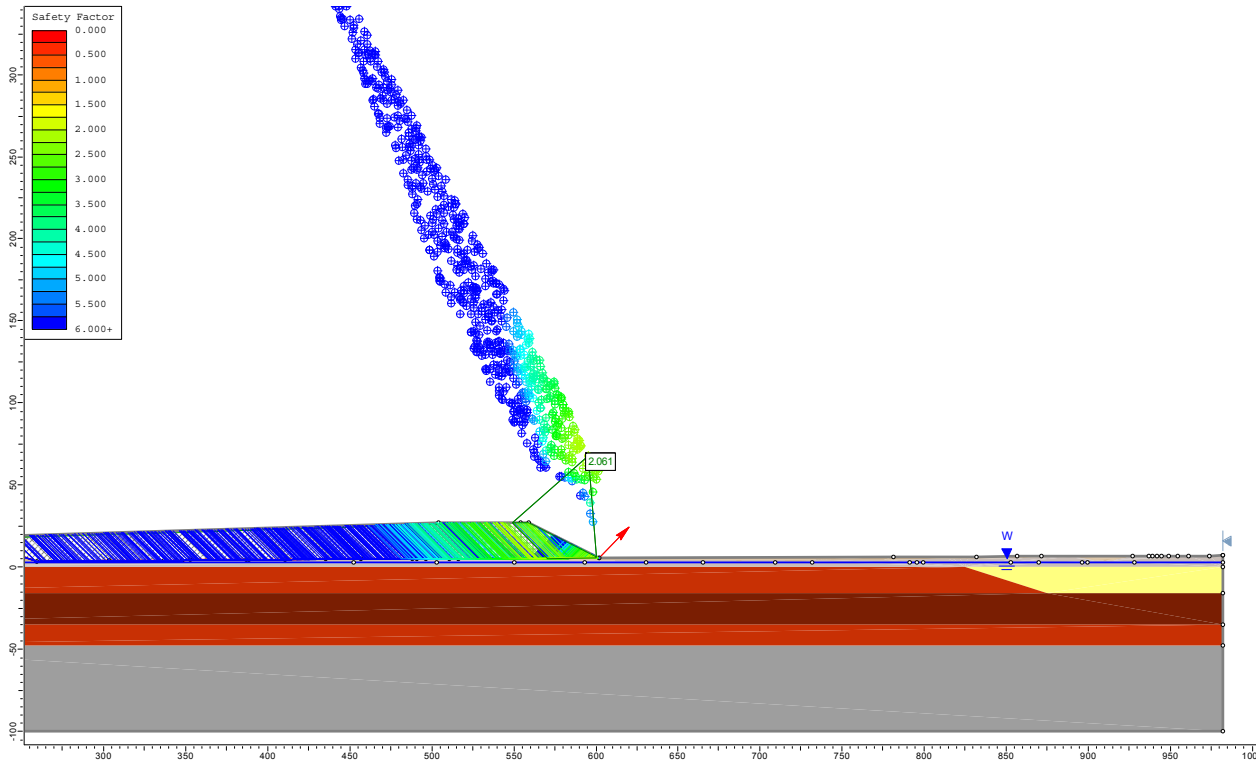
Global Minimums

Method: spencer

- FS: 2.061070
- Axis Location: 595.383, 67.523
- Left Slip Surface Endpoint: 549.169, 26.750
- Right Slip Surface Endpoint: 600.273, 6.088
- Resisting Moment=2.13185e+006 lb-ft
- Driving Moment=1.03435e+006 lb-ft
- Resisting Horizontal Force=29071.5 lb
- Driving Horizontal Force=14105.1 lb
- Total Slice Area=440.915 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 13a

Project Summary

- File Name: 13-bc2 Section A Interim Phase 1 Drained Peak Noncircular through Liner.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:12:40 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Left to Right
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 100
- Left Projection Angle (End Angle): 140
- Right Projection Angle (Start Angle): 30
- Right Projection Angle (End Angle): 70
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill	Cover
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120	120
Cohesion [psf]	430	575	0	430	575	430	250	250
Friction Angle [deg]	13.2	18.3	25	13.2	18.3	13.2	20	20
Water	Water	Water	Water Table	Water	Water	Water	Water Table	Water

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Surface	Table	Table		Table	Table	Table		Table
Hu Value	1	1	1	1	1	1	1	1

Property	Waste - Sludge	Liner	Waste - Impacted Soil
Color			
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	90	120	120
Cohesion [psf]	0	0	450
Friction Angle [deg]	5	8.6	15
Water Surface	Water Table	Water Table	Water Table
Hu Value	1	1	1

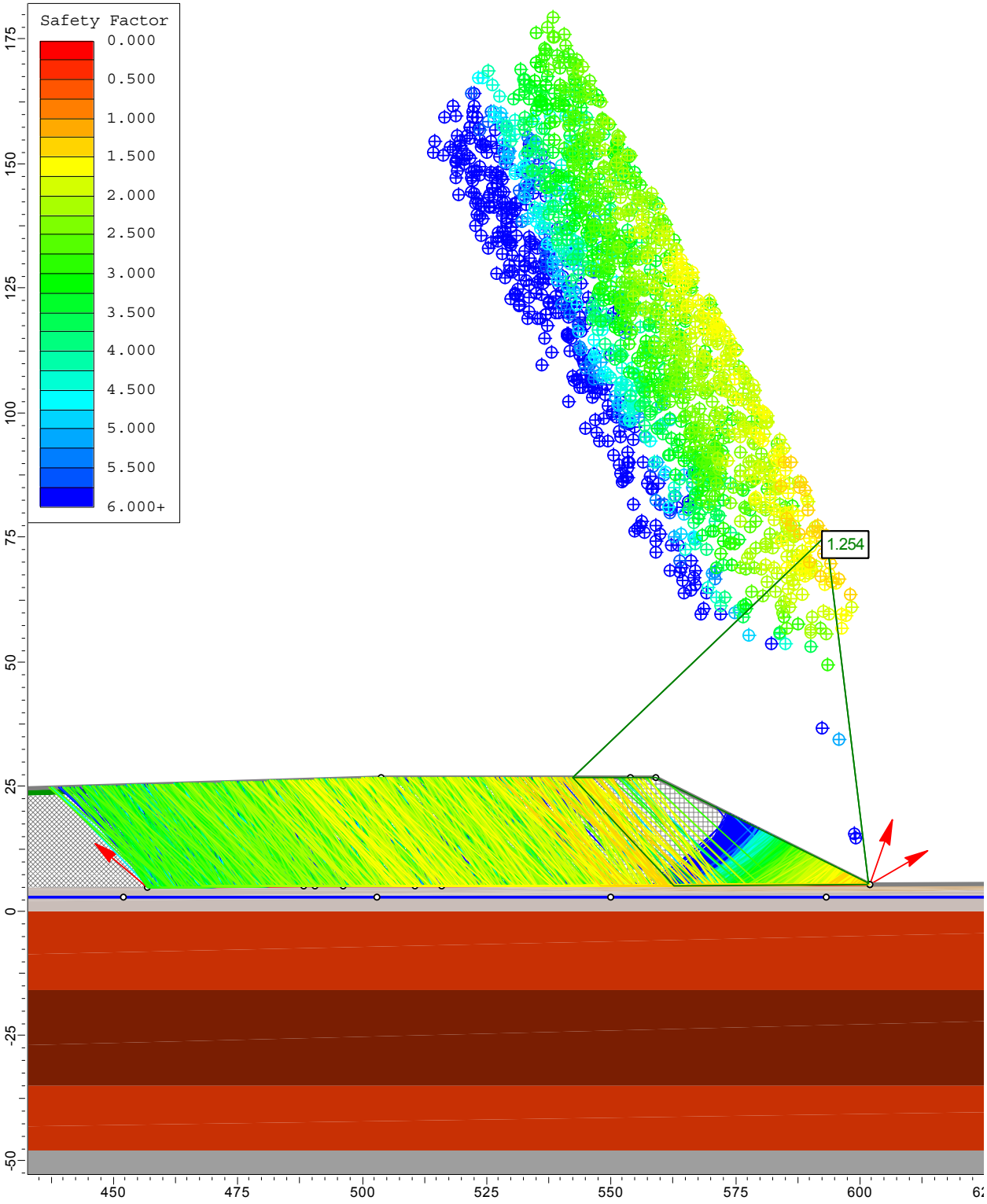
Global Minimums

Method: spencer

- FS: 1.253620
- Axis Location: 593.022, 75.453
- Left Slip Surface Endpoint: 542.114, 26.750
- Right Slip Surface Endpoint: 601.440, 5.505
- Resisting Moment=1.67668e+006 lb-ft
- Driving Moment=1.33747e+006 lb-ft
- Resisting Horizontal Force=18678 lb
- Driving Horizontal Force=14899.3 lb
- Total Slice Area=607.388 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 13b

Project Summary

- File Name: 13-bc4 Section A Interim Phase 1 Drained Large Disp Noncircular through Liner.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:12:40 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Left to Right
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 100
- Left Projection Angle (End Angle): 140
- Right Projection Angle (Start Angle): 30
- Right Projection Angle (End Angle): 70
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill	Cover
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120	120
Cohesion [psf]	430	575	0	430	575	430	250	250
Friction Angle [deg]	13.2	18.3	25	13.2	18.3	13.2	20	20
Water	Water	Water	Water Table	Water	Water	Water	Water Table	Water

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Surface	Table	Table		Table	Table	Table		Table
Hu Value	1	1	1	1	1	1	1	1

Property	Waste - Sludge	Liner	Waste - Impacted Soil
Color			
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	90	120	120
Cohesion [psf]	0	0	450
Friction Angle [deg]	5	4.8	15
Water Surface	Water Table	Water Table	Water Table
Hu Value	1	1	1

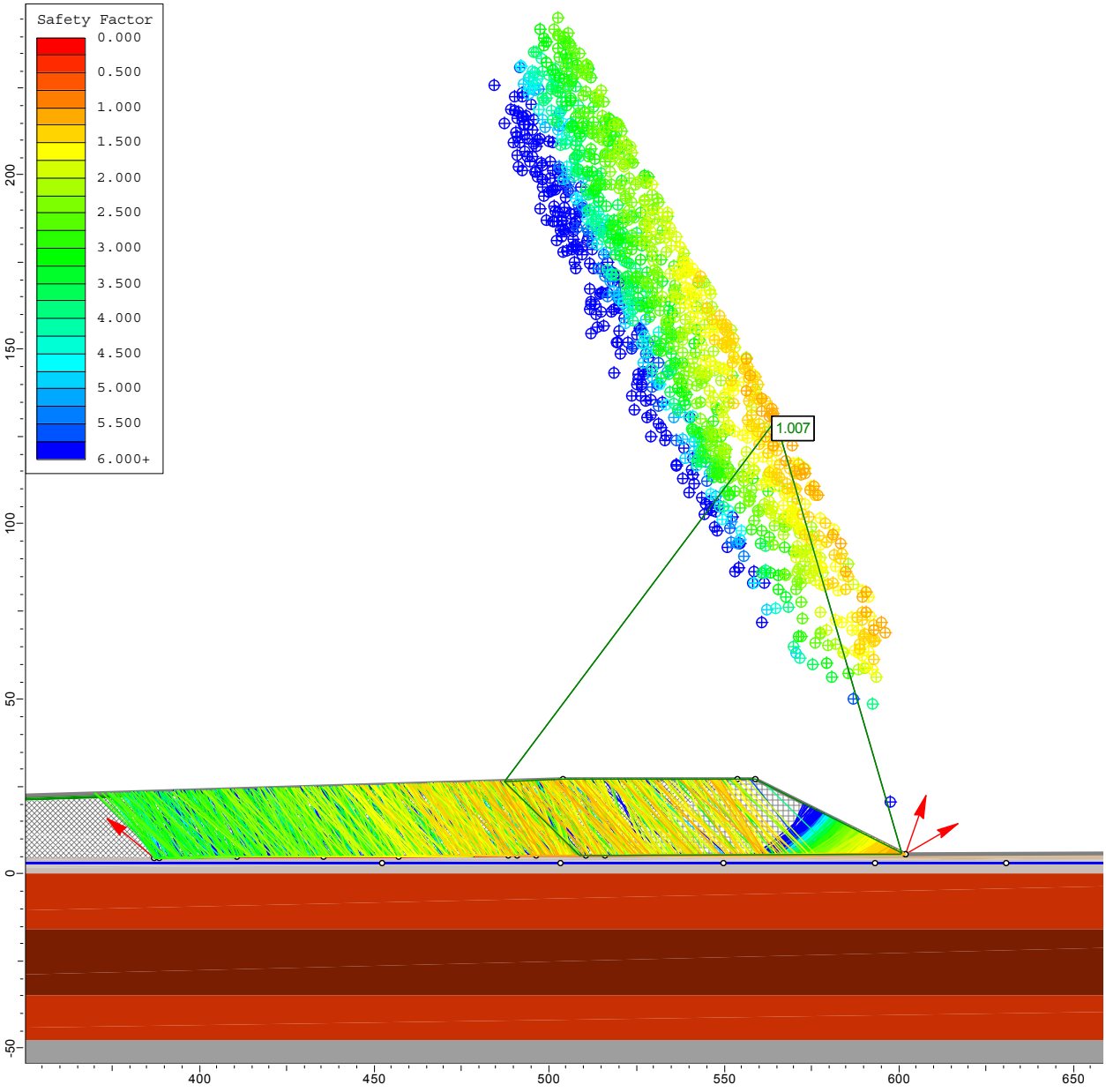
Global Minimums

Method: spencer

- FS: 1.006540
- Axis Location: 564.635, 129.772
- Left Slip Surface Endpoint: 487.217, 26.248
- Right Slip Surface Endpoint: 601.003, 5.723
- Resisting Moment=2.22139e+006 lb-ft
- Driving Moment=2.20697e+006 lb-ft
- Resisting Horizontal Force=16862.6 lb
- Driving Horizontal Force=16753.1 lb
- Total Slice Area=1792.79 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Run Number: 14

Project Summary

- File Name: 14 Section B Final Undrained Circular.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:15:46 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Circular
- Search Method: Auto Refine Search
- Divisions along slope: 12
- Circles per division: 12
- Number of iterations: 10
- Divisions to use in next iteration: 50%
- Composite Surfaces: Disabled
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill	Cover
Color								
Strength Type	Undrained	Undrained	Mohr-Coulomb	Undrained	Undrained	Undrained	Undrained	Undrained
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120	120
Cohesion [psf]			0					
Friction Angle [deg]			25					
Cohesio	1525	760		1630	1535	1615	1000	1000

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

n Type								
Water Surface	None	None	Water Table	None	None	None	None	None
Hu Value			1					
Ru Value	0	0		0	0	0	0	0

Property	Waste - Sludge	Liner	Waste - Impacted Soil
Color			
Strength Type	Mohr-Coulomb	Undrained	Undrained
Unit Weight [lbs/ft3]	90	120	120
Cohesion [psf]	0		
Friction Angle [deg]	5		
Cohesion Type		750	750
Water Surface	Water Table	None	None
Hu Value	1		
Ru Value		0	0

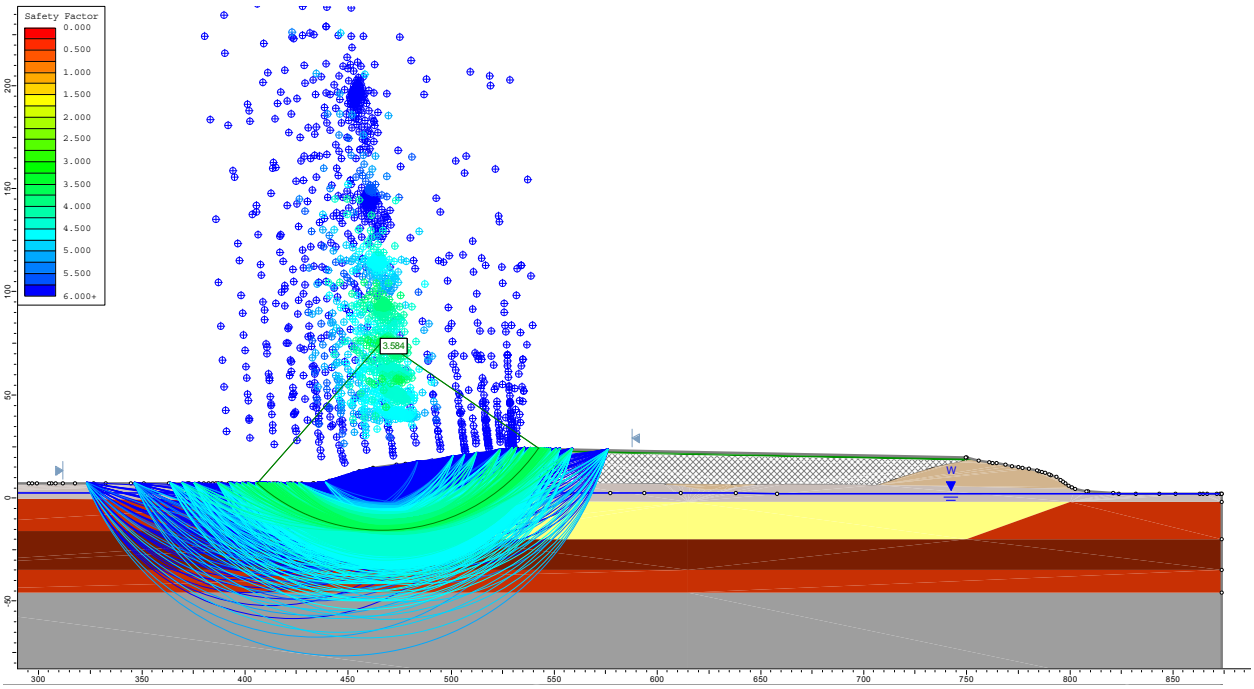
Global Minimums

Method: spencer

- FS: 3.584390
- Center: 466.814, 76.124
- Radius: 92.234
- Left Slip Surface Endpoint: 405.749, 6.999
- Right Slip Surface Endpoint: 542.741, 23.757
- Resisting Moment=1.41399e+007 lb-ft
- Driving Moment=3.94486e+006 lb-ft
- Resisting Horizontal Force=134683 lb
- Driving Horizontal Force=37574.8 lb
- Total Slice Area=2948.62 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 15

Project Summary

- File Name: 15 Section B Final Undrained Noncircular through Liner and Berm.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:15:46 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 100
- Left Projection Angle (End Angle): 140
- Right Projection Angle (Start Angle): 35
- Right Projection Angle (End Angle): 75
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill	Cover
Color								
Strength Type	Undrained	Undrained	Mohr-Coulomb	Undrained	Undrained	Undrained	Undrained	Undrained
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120	120
Cohesion [psf]			0					
Friction Angle [deg]			25					

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Cohesion Type	1525	760		1630	1535	1615	1000	1000
Water Surface	None	None	Water Table	None	None	None	None	None
Hu Value			1					
Ru Value	0	0		0	0	0	0	0

Property	Waste - Sludge	Liner	Waste - Impacted Soil
Color			
Strength Type	Mohr-Coulomb	Undrained	Undrained
Unit Weight [lbs/ft3]	90	120	120
Cohesion [psf]	0		
Friction Angle [deg]	5		
Cohesion Type		750	750
Water Surface	Water Table	None	None
Hu Value	1		
Ru Value		0	0

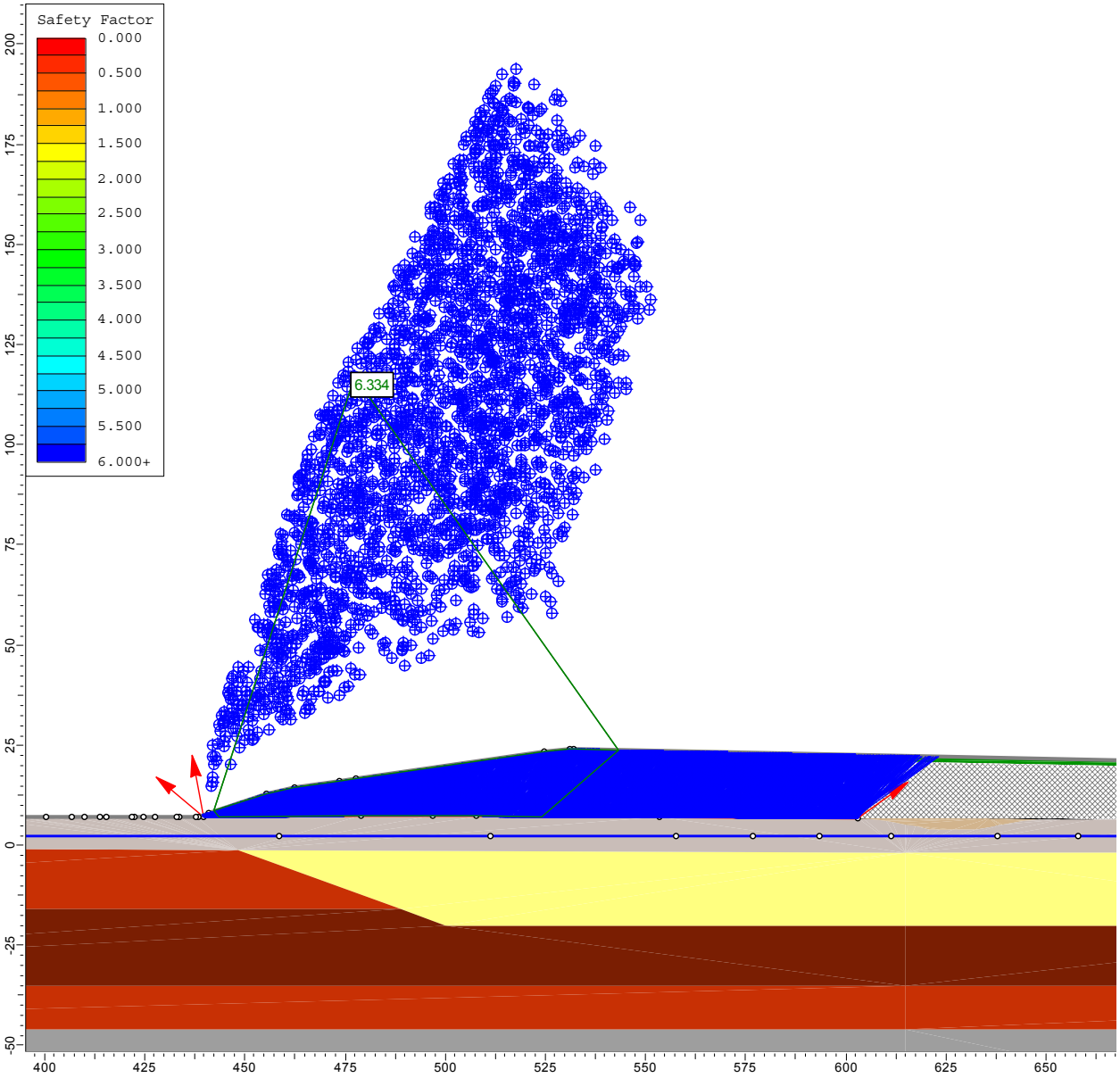
Global Minimums

Method: spencer

- FS: 6.333850
- Axis Location: 477.483, 116.915
- Left Slip Surface Endpoint: 442.340, 8.496
- Right Slip Surface Endpoint: 543.133, 23.749
- Resisting Moment=9.60997e+006 lb-ft
- Driving Moment=1.51724e+006 lb-ft
- Resisting Horizontal Force=82706.2 lb
- Driving Horizontal Force=13057.8 lb
- Total Slice Area=956.174 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 16

Project Summary

- File Name: 16 Section C Final Undrained Circular.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:16:59 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Left to Right
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Circular
- Search Method: Auto Refine Search
- Divisions along slope: 12
- Circles per division: 12
- Number of iterations: 10
- Divisions to use in next iteration: 50%
- Composite Surfaces: Disabled
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill	Cover
Color								
Strength Type	Undrained	Undrained	Mohr-Coulomb	Undrained	Undrained	Undrained	Undrained	Undrained
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120	120
Cohesion [psf]			0					
Friction Angle [deg]			25					
Cohesio	1525	760		1630	1535	1615	1000	1000

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

n Type								
Water Surface	None	None	Water Table	None	None	None	None	None
Hu Value			1					
Ru Value	0	0		0	0	0	0	0

Property	Waste - Sludge	Liner
Color		
Strength Type	Mohr-Coulomb	Undrained
Unit Weight [lbs/ft3]	90	120
Cohesion [psf]	0	
Friction Angle [deg]	5	
Cohesion Type		750
Water Surface	Water Table	None
Hu Value	1	
Ru Value		0

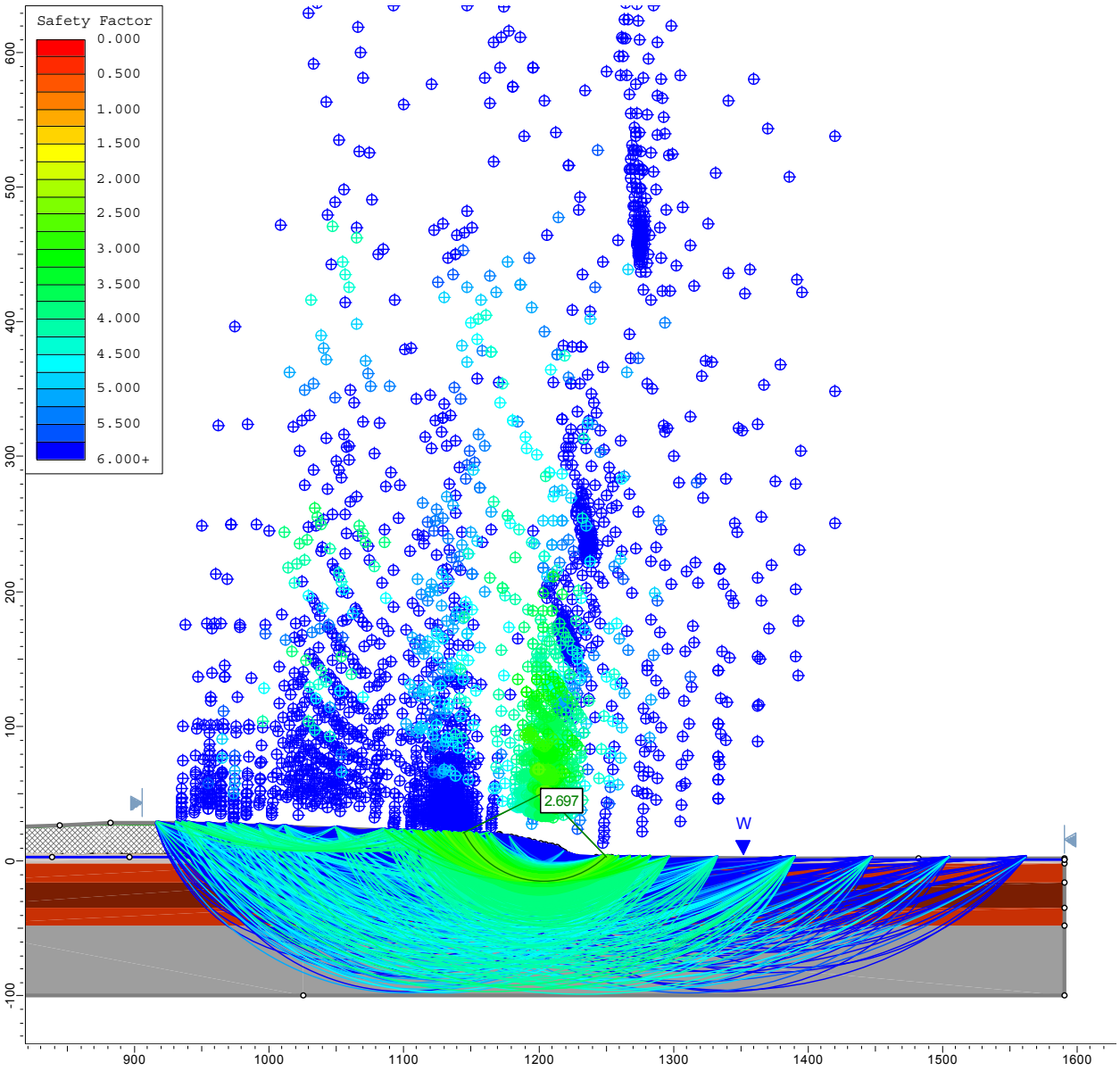
Global Minimums

Method: spencer

- FS: 2.696530
- Center: 1203.934, 50.837
- Radius: 66.826
- Left Slip Surface Endpoint: 1144.265, 20.748
- Right Slip Surface Endpoint: 1250.188, 2.605
- Resisting Moment=7.04607e+006 lb-ft
- Driving Moment=2.61301e+006 lb-ft
- Resisting Horizontal Force=89313.4 lb
- Driving Horizontal Force=33121.6 lb
- Total Slice Area=2117 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Run Number: 17

Project Summary

- File Name: 17 Section C Final Undrained Noncircular through Liner and Berm.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:16:59 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Left to Right
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 135
- Left Projection Angle (End Angle): 135
- Right Projection Angle (Start Angle): 45
- Right Projection Angle (End Angle): 45
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill	Cover
Color								
Strength Type	Undrained	Undrained	Mohr-Coulomb	Undrained	Undrained	Undrained	Undrained	Undrained
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120	120
Cohesion [psf]			0					
Friction Angle [deg]			25					

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Cohesion Type	1525	760		1630	1535	1615	1000	1000
Water Surface	None	None	Water Table	None	None	None	None	None
Hu Value			1					
Ru Value	0	0		0	0	0	0	0

Property	Waste - Sludge	Liner
Color		
Strength Type	Mohr-Coulomb	Undrained
Unit Weight [lbs/ft3]	90	120
Cohesion [psf]	0	
Friction Angle [deg]	5	
Cohesion Type		750
Water Surface	Water Table	None
Hu Value	1	
Ru Value		0

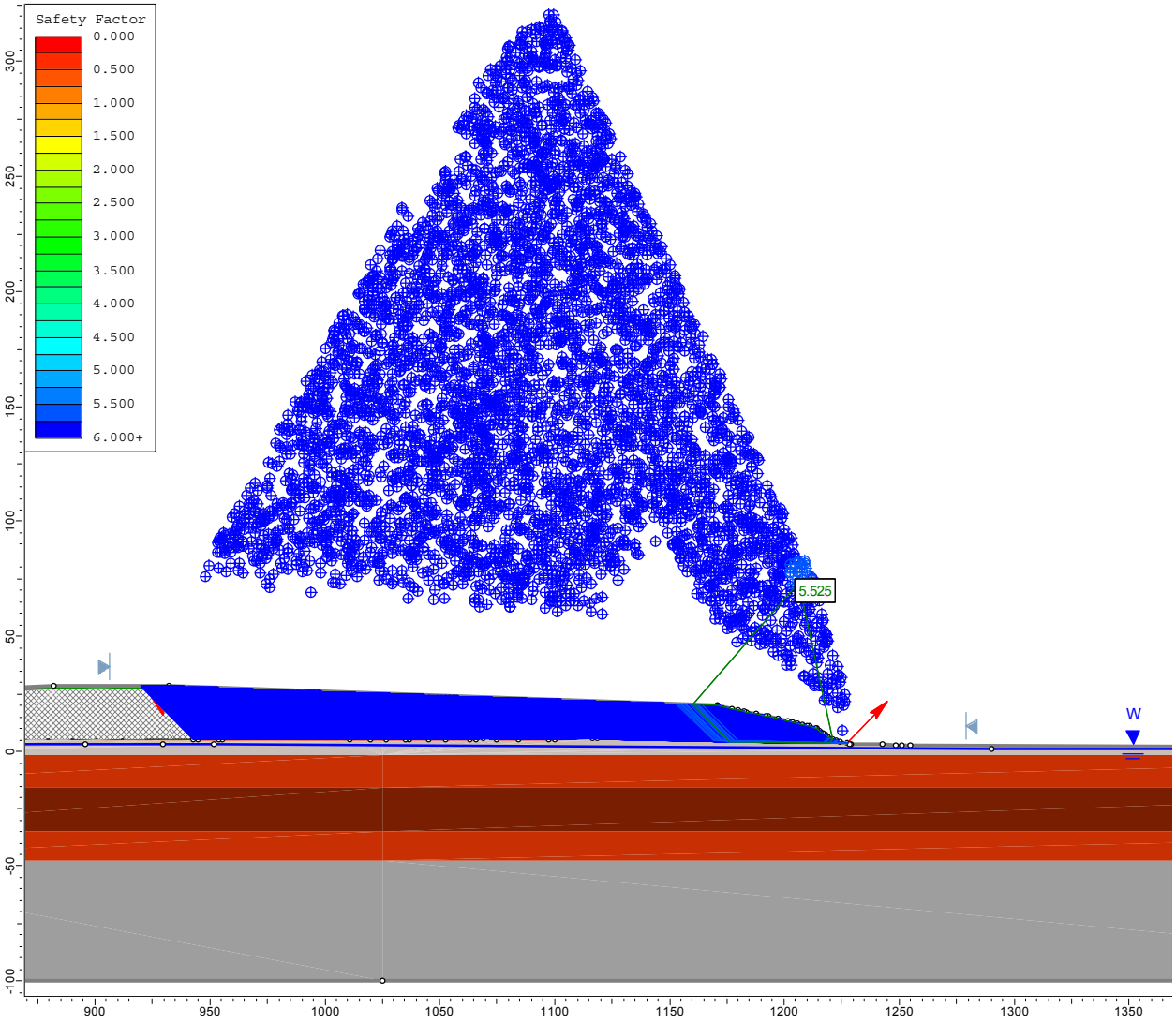
Global Minimums

Method: spencer

- FS: 5.524970
- Axis Location: 1205.905, 73.311
- Left Slip Surface Endpoint: 1160.266, 20.182
- Right Slip Surface Endpoint: 1221.025, 4.922
- Resisting Moment=4.51745e+006 lb-ft
- Driving Moment=817642 lb-ft
- Resisting Horizontal Force=58716.5 lb
- Driving Horizontal Force=10627.5 lb
- Total Slice Area=538.855 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Run Number: 18

Project Summary

- File Name: 18 Section D Final Undrained Circular.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:17:27 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Circular
- Search Method: Auto Refine Search
- Divisions along slope: 12
- Circles per division: 12
- Number of iterations: 10
- Divisions to use in next iteration: 50%
- Composite Surfaces: Disabled
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Slurry Wall	Levee/Berm/Fill
Color								
Strength Type	Undrained	Undrained	Mohr-Coulomb	Undrained	Undrained	Undrained	Undrained	Undrained
Unit Weight [lbs/ft3]	128	127	125	124	124	112	90	120
Cohesion [psf]			0					
Friction Angle [deg]			25					
Cohesio	1525	760		1630	1535	1615	0	1000

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

n Type								
Water Surface	None	None	Water Table	None	None	None	None	None
Hu Value			1					
Ru Value	0	0		0	0	0	0	0

Property	Cover	Waste - Sludge	Liner
Color			
Strength Type	Undrained	Mohr-Coulomb	Undrained
Unit Weight [lbs/ft3]	120	90	120
Cohesion [psf]		0	
Friction Angle [deg]		5	
Cohesion Type	1000		750
Water Surface	None	Water Table	None
Hu Value		1	
Ru Value	0		0

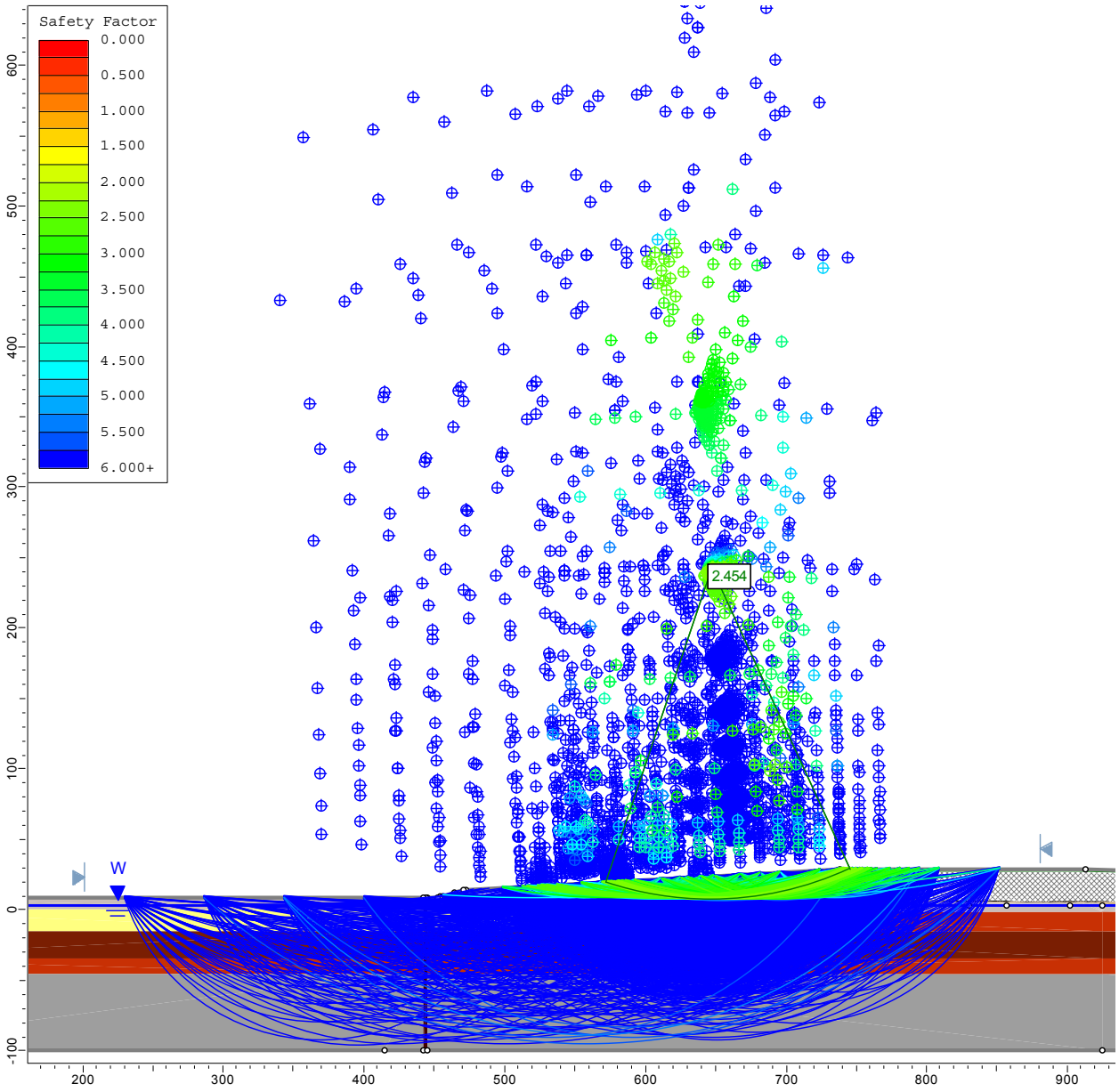
Global Minimums

Method: spencer

- FS: 2.454160
- Center: 646.999, 242.268
- Radius: 235.743
- Left Slip Surface Endpoint: 571.488, 18.946
- Right Slip Surface Endpoint: 745.848, 28.250
- Resisting Moment=5.73061e+006 lb-ft
- Driving Moment=2.33506e+006 lb-ft
- Resisting Horizontal Force=23522.3 lb
- Driving Horizontal Force=9584.7 lb
- Total Slice Area=1997.2 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 19

Project Summary

- File Name: 19 Section D Final Undrained Noncircular through Waste.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:17:27 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 100
- Left Projection Angle (End Angle): 140
- Right Projection Angle (Start Angle): 30
- Right Projection Angle (End Angle): 70
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Slurry Wall	Levee/Berm/Fill
Color								
Strength Type	Undrained	Undrained	Mohr-Coulomb	Undrained	Undrained	Undrained	Undrained	Undrained
Unit Weight [lbs/ft3]	128	127	125	124	124	112	90	120
Cohesion [psf]			0					
Friction Angle [deg]			25					

Cohesion Type	1525	760		1630	1535	1615	0	1000
Water Surface	None	None	Water Table	None	None	None	None	None
Hu Value			1					
Ru Value	0	0		0	0	0	0	0

Property	Cover	Waste - Sludge	Liner
Color			
Strength Type	Undrained	Mohr-Coulomb	Undrained
Unit Weight [lbs/ft3]	120	90	120
Cohesion [psf]		0	
Friction Angle [deg]		5	
Cohesion Type	1000		750
Water Surface	None	Water Table	None
Hu Value		1	
Ru Value	0		0

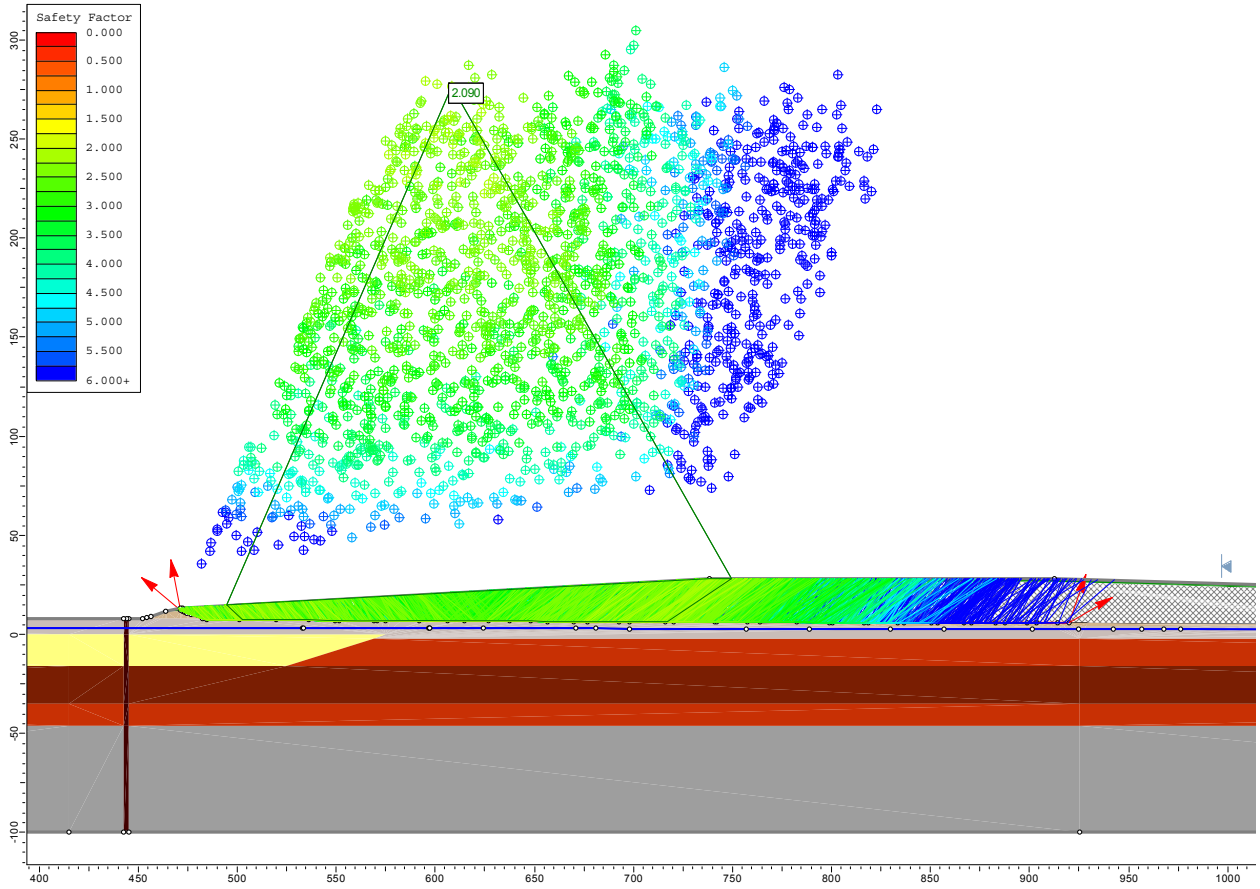
Global Minimums

Method: spencer

- FS: 2.090000
- Axis Location: 608.381, 276.363
- Left Slip Surface Endpoint: 494.522, 14.652
- Right Slip Surface Endpoint: 749.434, 28.250
- Resisting Moment=9.10059e+006 lb-ft
- Driving Moment=4.35435e+006 lb-ft
- Resisting Horizontal Force=31755.7 lb
- Driving Horizontal Force=15194.1 lb
- Total Slice Area=3432.65 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 20

Project Summary

- File Name: 20 Section B Final Drained Circular.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:15:46 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Circular
- Search Method: Auto Refine Search
- Divisions along slope: 12
- Circles per division: 12
- Number of iterations: 10
- Divisions to use in next iteration: 50%
- Composite Surfaces: Disabled
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill	Cover
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120	120
Cohesion [psf]	430	575	0	430	575	430	250	250
Friction Angle [deg]	13.2	18.3	25	13.2	18.3	13.2	20	20
Water Surface	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table

Hu Value	1	1	1	1	1	1	1	1

Property	Waste - Sludge	Liner	Waste - Impacted Soil
Color			
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	90	120	120
Cohesion [psf]	0	250	450
Friction Angle [deg]	5	15	15
Water Surface	Water Table	Water Table	Water Table
Hu Value	1	1	1

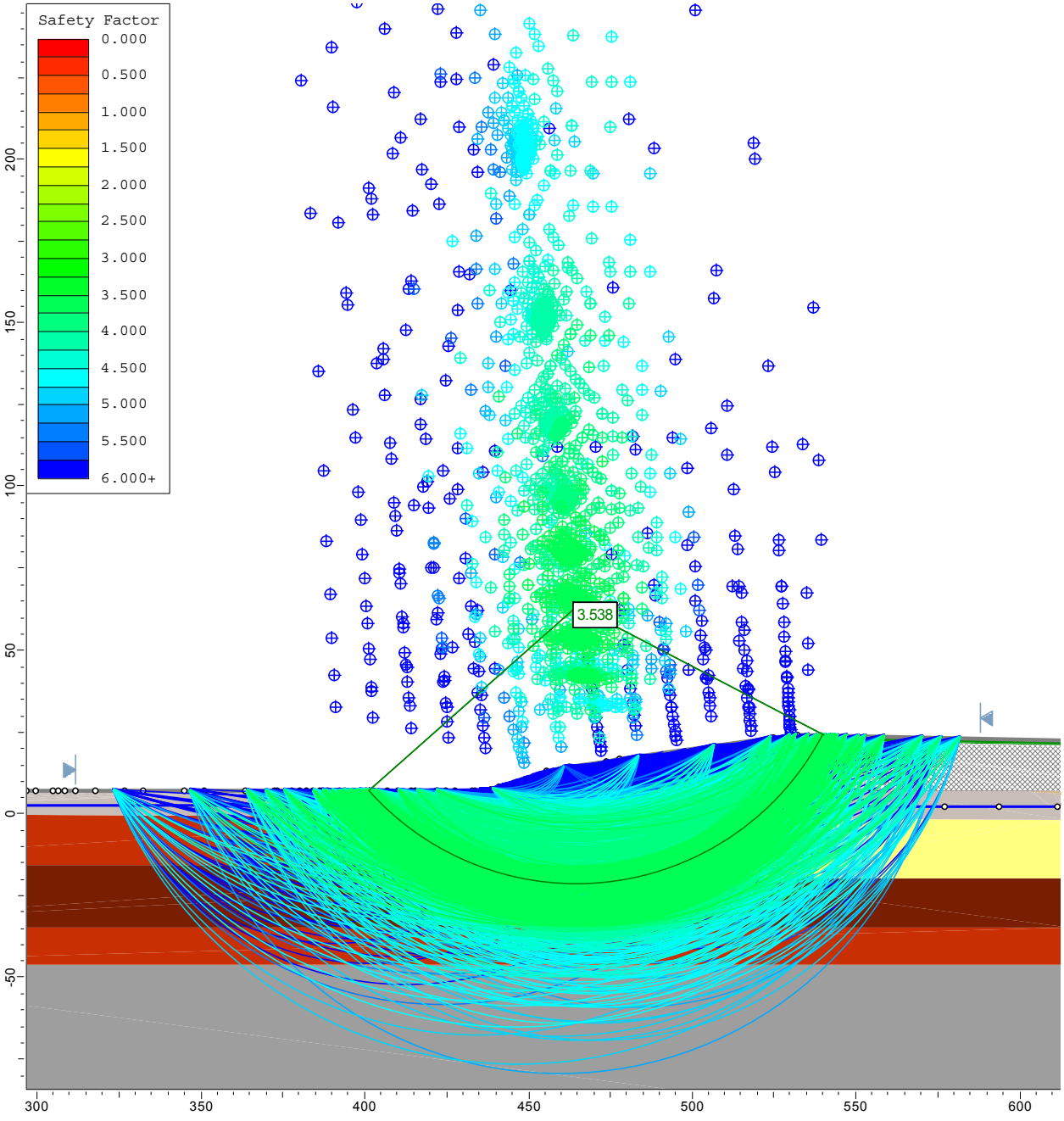
Global Minimums

Method: spencer

- FS: 3.537570
- Center: 464.815, 63.390
- Radius: 85.139
- Left Slip Surface Endpoint: 401.027, 7.000
- Right Slip Surface Endpoint: 540.193, 23.808
- Resisting Moment=1.42807e+007 lb-ft
- Driving Moment=4.03688e+006 lb-ft
- Resisting Horizontal Force=146648 lb
- Driving Horizontal Force=41454.5 lb
- Total Slice Area=3535.32 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 21

Project Summary

- File Name: 21 Section B Final Drained Noncircular through Liner and Berm.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:15:46 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 100
- Left Projection Angle (End Angle): 140
- Right Projection Angle (Start Angle): 35
- Right Projection Angle (End Angle): 75
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill	Cover
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120	120
Cohesion [psf]	430	575	0	430	575	430	250	250
Friction Angle [deg]	13.2	18.3	25	13.2	18.3	13.2	20	20
Water	Water	Water	Water Table	Water	Water	Water	Water Table	Water

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Surface	Table	Table		Table	Table	Table		Table
Hu Value	1	1	1	1	1	1	1	1

Property	Waste - Sludge	Liner	Waste - Impacted Soil
Color			
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	90	120	120
Cohesion [psf]	0	250	450
Friction Angle [deg]	5	15	15
Water Surface	Water Table	Water Table	Water Table
Hu Value	1	1	1

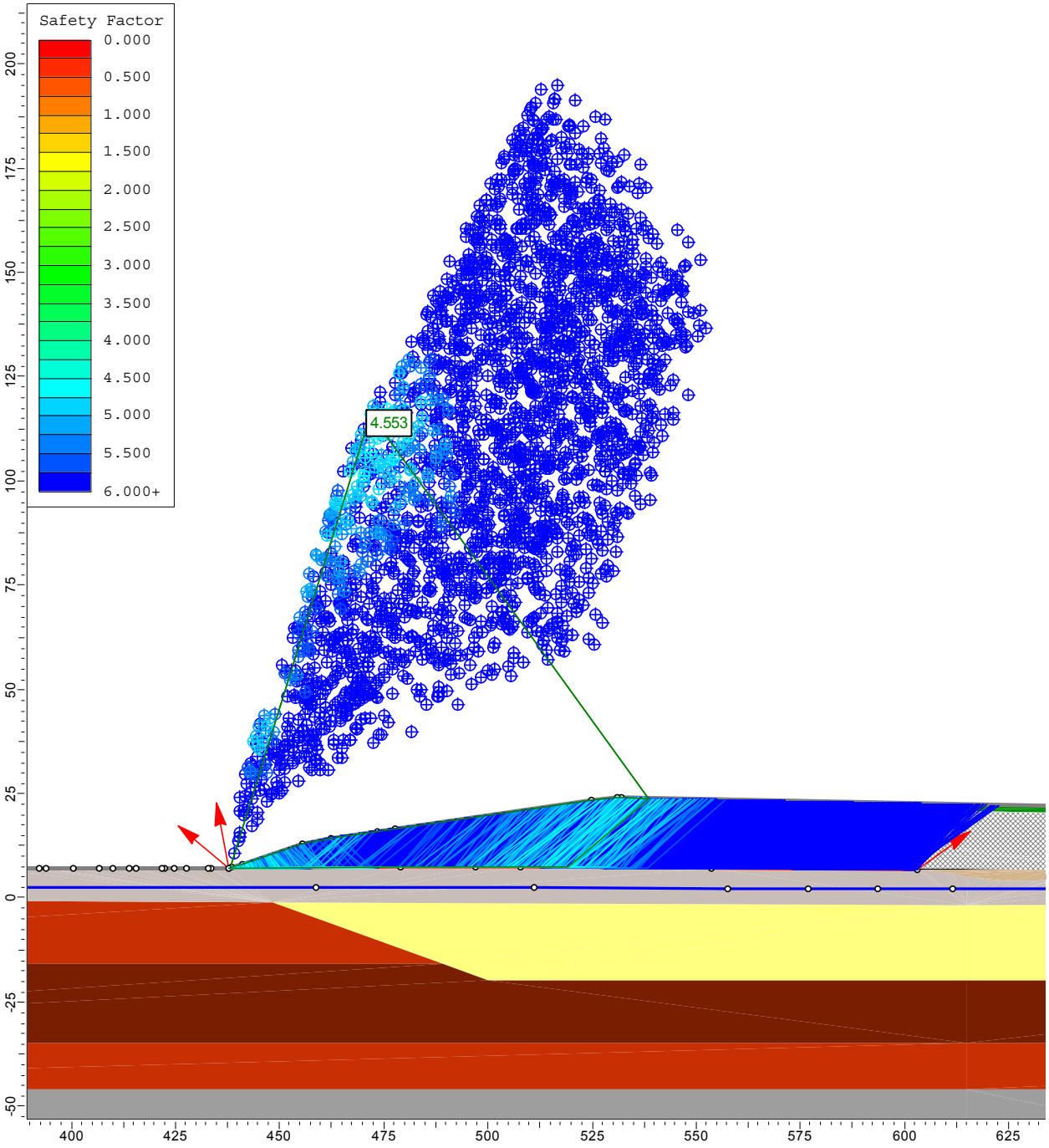
Global Minimums

Method: spencer

- FS: 4.552690
- Axis Location: 471.662, 115.858
- Left Slip Surface Endpoint: 438.197, 7.115
- Right Slip Surface Endpoint: 538.578, 23.840
- Resisting Moment=6.7945e+006 lb-ft
- Driving Moment=1.49242e+006 lb-ft
- Resisting Horizontal Force=58199.2 lb
- Driving Horizontal Force=12783.5 lb
- Total Slice Area=882.495 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 22

Project Summary

- File Name: 22 Section C Final Drained Circular.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:16:59 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Left to Right
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Circular
- Search Method: Auto Refine Search
- Divisions along slope: 12
- Circles per division: 12
- Number of iterations: 10
- Divisions to use in next iteration: 50%
- Composite Surfaces: Disabled
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill	Cover
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120	120
Cohesion [psf]	430	575	0	430	575	430	250	250
Friction Angle [deg]	13.2	18.3	25	13.2	18.3	13.2	20	20
Water Surface	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table

Hu Value	1	1	1	1	1	1	1	1

Property	Waste - Sludge	Liner
Color		
Strength Type	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	90	120
Cohesion [psf]	0	250
Friction Angle [deg]	5	15
Water Surface	Water Table	Water Table
Hu Value	1	1

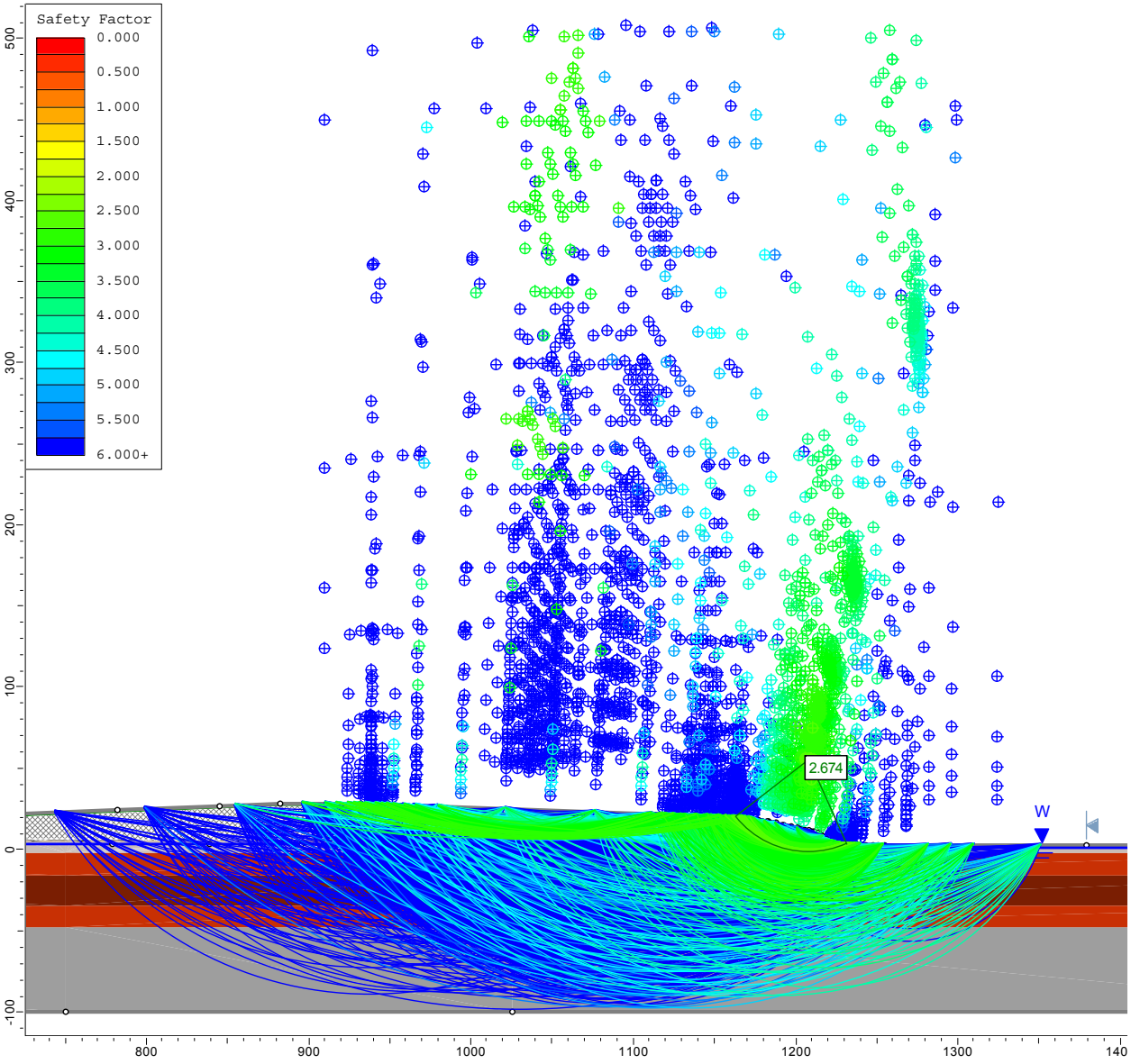
Global Minimums

Method: spencer

- FS: 2.674290
- Center: 1208.339, 55.394
- Radius: 57.383
- Left Slip Surface Endpoint: 1163.108, 20.082
- Right Slip Surface Endpoint: 1231.623, 2.948
- Resisting Moment=2.78276e+006 lb-ft
- Driving Moment=1.04056e+006 lb-ft
- Resisting Horizontal Force=44831.1 lb
- Driving Horizontal Force=16763.7 lb
- Total Slice Area=681.063 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 23

Project Summary

- File Name: 23 Section C Final Drained Noncircular through Stratum I.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:16:59 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Left to Right
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 100
- Left Projection Angle (End Angle): 140
- Right Projection Angle (Start Angle): 30
- Right Projection Angle (End Angle): 70
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Levee/Berm/Fill	Cover
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	128	127	125	124	124	112	120	120
Cohesion [psf]	430	575	0	430	575	430	250	250
Friction Angle [deg]	13.2	18.3	25	13.2	18.3	13.2	20	20
Water	Water	Water	Water Table	Water	Water	Water	Water Table	Water

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Surface	Table	Table		Table	Table	Table		Table
Hu Value	1	1	1	1	1	1	1	1

Property	Waste - Sludge	Liner
Color		
Strength Type	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	90	120
Cohesion [psf]	0	250
Friction Angle [deg]	5	15
Water Surface	Water Table	Water Table
Hu Value	1	1

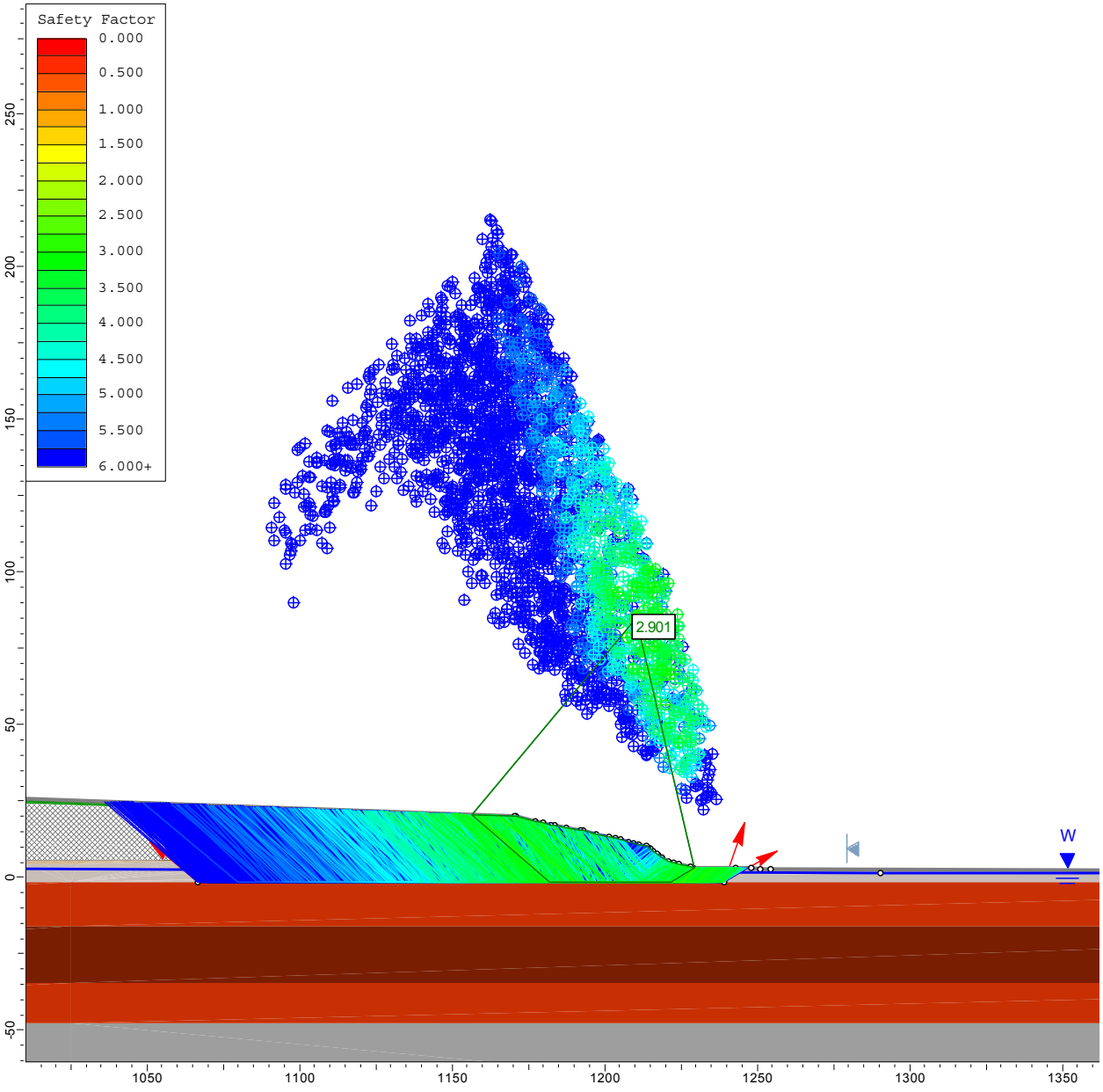
Global Minimums

Method: spencer

- FS: 2.900890
- Axis Location: 1210.347, 84.611
- Left Slip Surface Endpoint: 1156.543, 20.314
- Right Slip Surface Endpoint: 1229.502, 2.989
- Resisting Moment=4.70158e+006 lb-ft
- Driving Moment=1.62074e+006 lb-ft
- Resisting Horizontal Force=50007.8 lb
- Driving Horizontal Force=17238.8 lb
- Total Slice Area=850.072 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 24

Project Summary

- File Name: 24 Section D Final Drained Circular.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:17:27 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Circular
- Search Method: Auto Refine Search
- Divisions along slope: 12
- Circles per division: 12
- Number of iterations: 10
- Divisions to use in next iteration: 50%
- Composite Surfaces: Disabled
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Slurry Wall	Levee/Berm/Fill
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	128	127	125	124	124	112	90	120
Cohesion [psf]	430	575	0	430	575	430	0	250
Friction Angle [deg]	13.2	18.3	25	13.2	18.3	13.2	0	20
Water Surface	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Hu Value	1	1	1	1	1	1	1	1

Property	Cover	Waste - Sludge	Liner
Color			
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	120	90	120
Cohesion [psf]	250	0	250
Friction Angle [deg]	20	5	15
Water Surface	Water Table	Water Table	Water Table
Hu Value	1	1	1

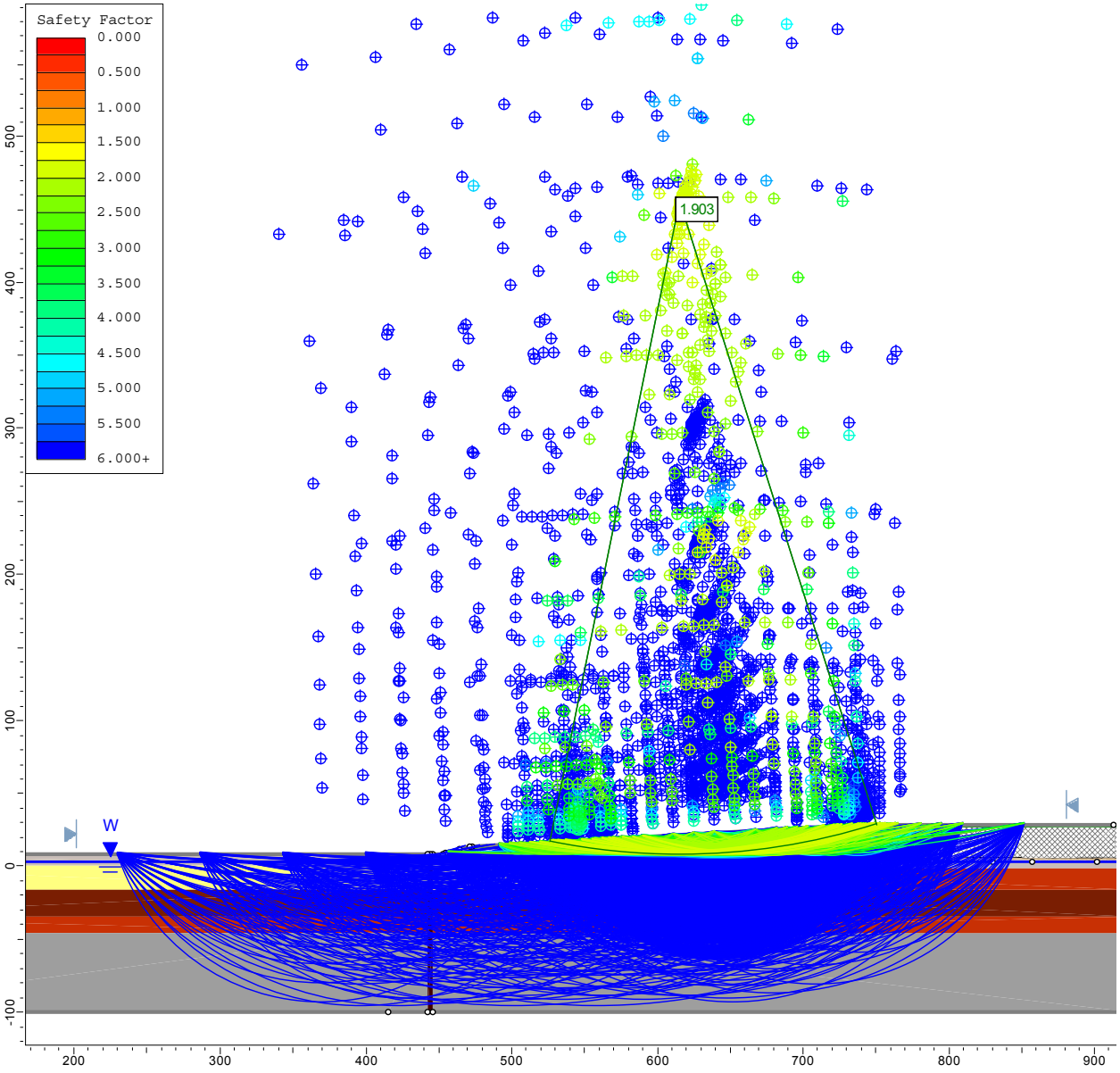
Global Minimums

Method: spencer

- FS: 1.903250
- Center: 615.454, 455.598
- Radius: 448.130
- Left Slip Surface Endpoint: 526.301, 16.425
- Right Slip Surface Endpoint: 750.342, 28.250
- Resisting Moment=9.60021e+006 lb-ft
- Driving Moment=5.04412e+006 lb-ft
- Resisting Horizontal Force=21183.5 lb
- Driving Horizontal Force=11130.2 lb
- Total Slice Area=2208.48 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Run Number: 25

Project Summary

- File Name: 25 Section D Final Drained Noncircular through Waste.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:17:27 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 100
- Left Projection Angle (End Angle): 140
- Right Projection Angle (Start Angle): 30
- Right Projection Angle (End Angle): 70
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Slurry Wall	Levee/Berm/Fill
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	128	127	125	124	124	112	90	120
Cohesion [psf]	430	575	0	430	575	430	0	250
Friction Angle [deg]	13.2	18.3	25	13.2	18.3	13.2	0	20
Water	Water	Water	Water Table	Water	Water	Water	Water	Water Table

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Surface	Table	Table		Table	Table	Table	Table	
Hu Value	1	1	1	1	1	1	1	1

Property	Cover	Waste - Sludge	Liner
Color			
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	120	90	120
Cohesion [psf]	250	0	250
Friction Angle [deg]	20	5	15
Water Surface	Water Table	Water Table	Water Table
Hu Value	1	1	1

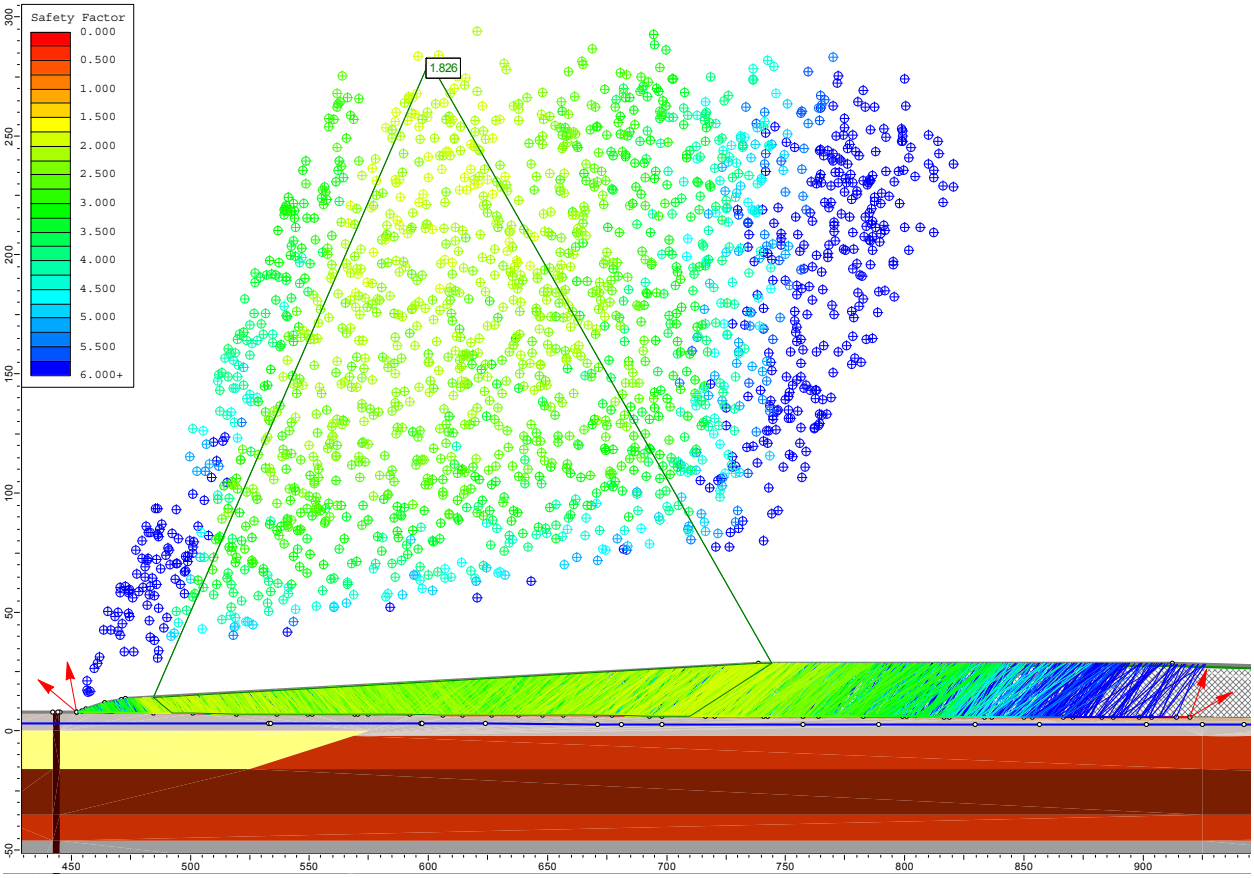
Global Minimums

Method: spencer

- FS: 1.825890
- Axis Location: 600.172, 281.008
- Left Slip Surface Endpoint: 484.414, 14.089
- Right Slip Surface Endpoint: 744.253, 28.250
- Resisting Moment=8.16076e+006 lb-ft
- Driving Moment=4.46946e+006 lb-ft
- Resisting Horizontal Force=28638.6 lb
- Driving Horizontal Force=15684.7 lb
- Total Slice Area=3372.63 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 26

Project Summary

- File Name: 26-bc6 Section D Final Drained Peak Noncircular through Liner.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:17:27 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: Y. Bholat Date: 8/29/2014 Reviewed by: S. Graves Date: 9/2/2014

Client: ENTACT, LLC Project: Malone Service Company Superfund Site Project No.: TXL0299 Phase No.: 02

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 100
- Left Projection Angle (End Angle): 140
- Right Projection Angle (Start Angle): 30
- Right Projection Angle (End Angle): 70
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Slurry Wall	Levee/Berm/Fill
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	128	127	125	124	124	112	90	120
Cohesion [psf]	430	575	0	430	575	430	0	250
Friction Angle [deg]	13.2	18.3	25	13.2	18.3	13.2	0	20
Water	Water	Water	Water Table	Water	Water	Water	Water	Water Table

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Surface	Table	Table		Table	Table	Table	Table	
Hu Value	1	1	1	1	1	1	1	1

Property	Cover	Waste - Sludge	Liner
Color			
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	120	90	120
Cohesion [psf]	250	0	0
Friction Angle [deg]	20	5	4
Water Surface	Water Table	Water Table	Water Table
Hu Value	1	1	1

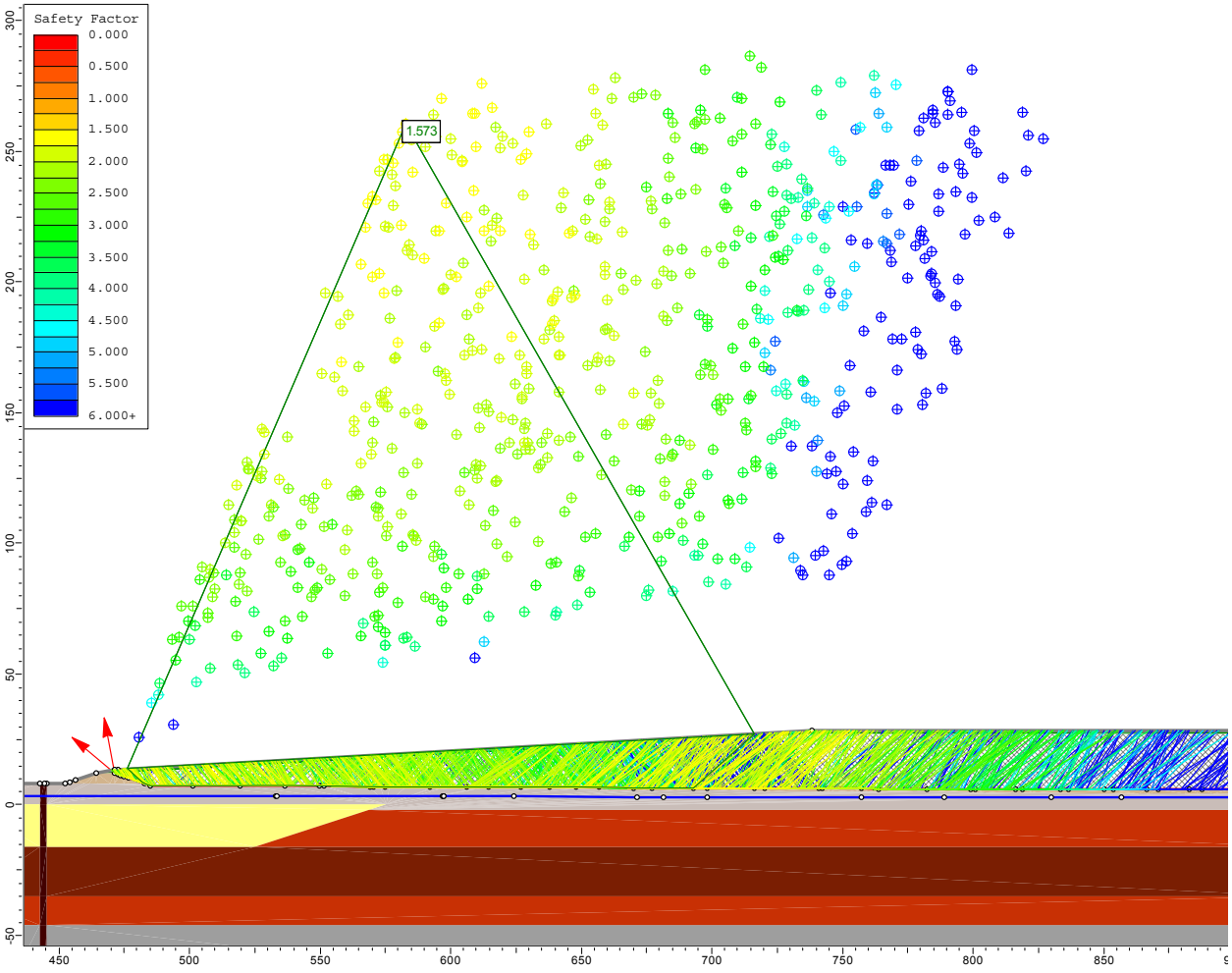
Global Minimums

Method: spencer

- FS: 1.573260
- Axis Location: 582.492, 260.434
- Left Slip Surface Endpoint: 475.824, 13.609
- Right Slip Surface Endpoint: 715.951, 27.004
- Resisting Moment=5.57283e+006 lb-ft
- Driving Moment=3.54221e+006 lb-ft
- Resisting Horizontal Force=20854.1 lb
- Driving Horizontal Force=13255.3 lb
- Total Slice Area=2984.43 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**



Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Run Number: 27

Project Summary

- File Name: 27-bc6 Section D Final Drained Large Disp Noncircular through Liner.slim
- Slide Modeler Version: 6.029
- Project Title: Malone Service Company Superfund Site
- Analysis: Slope Stability
- Company: Geosyntec Consultants
- Date Created: 7/24/2014, 9:17:27 AM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 100
- Left Projection Angle (End Angle): 140
- Right Projection Angle (Start Angle): 30
- Right Projection Angle (End Angle): 70
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Stratum I	Stratum II	Stratum IIa Paleochannel	Stratum III	Stratum IV	Stratum V	Slurry Wall	Levee/Berm/Fill
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	128	127	125	124	124	112	90	120
Cohesion [psf]	430	575	0	430	575	430	0	250
Friction Angle [deg]	13.2	18.3	25	13.2	18.3	13.2	0	20
Water	Water	Water	Water Table	Water	Water	Water	Water	Water Table

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Surface	Table	Table		Table	Table	Table	Table	
Hu Value	1	1	1	1	1	1	1	1

Property	Cover	Waste - Sludge	Liner
Color			
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	120	90	120
Cohesion [psf]	250	0	0
Friction Angle [deg]	20	5	3
Water Surface	Water Table	Water Table	Water Table
Hu Value	1	1	1

Global Minimums

Method: spencer

- FS: 1.261840
- Axis Location: 582.492, 260.434
- Left Slip Surface Endpoint: 475.824, 13.609
- Right Slip Surface Endpoint: 715.951, 27.004
- Resisting Moment=4.42881e+006 lb-ft
- Driving Moment=3.50979e+006 lb-ft
- Resisting Horizontal Force=16356 lb
- Driving Horizontal Force=12962 lb
- Total Slice Area=2984.43 ft2

Written by: **Y. Bholat** Date: **8/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT, LLC** Project: **Malone Service Company Superfund Site** Project No.: **TXL0299** Phase No.: **02**

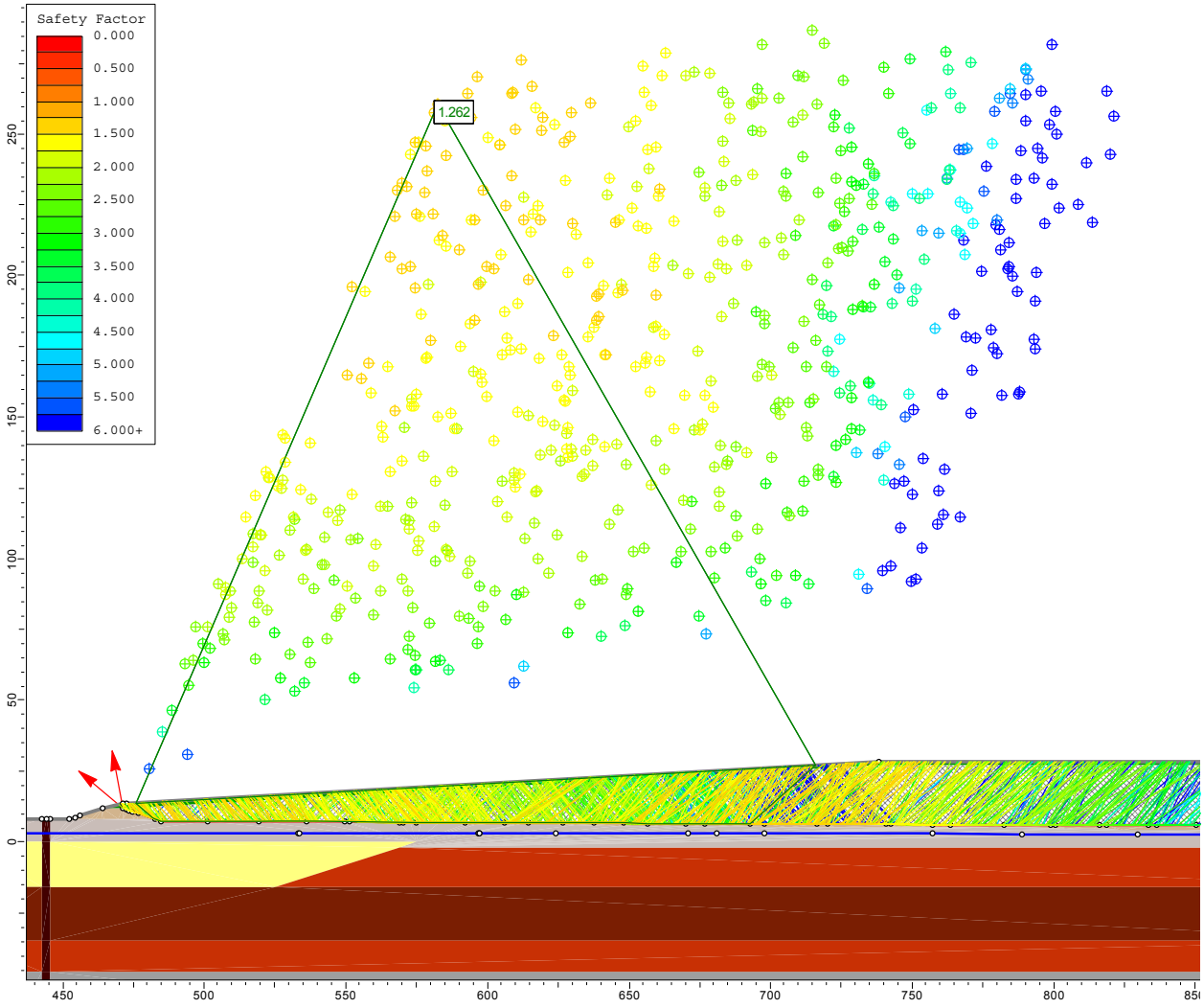


EXHIBIT 4
LCS/LDS DESIGN

LEACHATE GENERATION RATES AND HEAD ON LINER (HELP MODELING)

Written by: **A. Brown** Date: **7/28/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT** Project: **Malone Superfund Site** Project No.: **TXL0299** Phase No.: **02**

LEACHATE GENERATION RATES AND HEAD ON LINER (*HELP* MODELING)

GEOSYNTEC CONSULTANTS, INC.
TEXAS ENGINEERING FIRM
REGISTRATION NO. F-1182

SEALED FOR CALCULATION PAGES
1 THROUGH 33

1. INTRODUCTION

The purposes of this analysis are to:

- estimate the design leachate generation rates for various operation conditions;
- calculate the design hydraulic conductivity and transmissivity of the leachate drainage layer in the leachate collection system; and
- evaluate the maximum leachate head on the liner system for compliance with the Federal regulations, which require the maximum head of leachate to be less than 30 cm (12 in.) [40 CFR Part 264].

2. METHOD OF ANALYSIS

The leachate collection rates and maximum leachate head on the liner system were estimated using the Hydrologic Evaluation of Landfill Performance (*HELP*) computer model, Version 3.07, developed by the U.S. Environmental Protection Agency (USEPA). The *HELP* model simulates hydrologic processes for a landfill by performing daily, sequential water balance analyses using a quasi-two-dimensional, deterministic approach (Schroeder et al., 1994a, 1994b).

The hydrologic processes considered in the *HELP* model include precipitation, surface-water evaporation, runoff, infiltration, plant transpiration, soil water evaporation, soil water storage, vertical drainage (saturated and unsaturated), lateral drainage (saturated), vertical drainage

(saturated) through compacted soil liners and geosynthetic clay liners (GCLs), and leakage through geomembranes.

3. ANALYSIS CASES AND SCENARIOS

Leachate generation rates during four operational scenarios for the Malone Service Company Superfund Site RCRA Subtitle C Cell are considered in this analysis. The leachate collection rate and maximum leachate head on the floor of the liner system were calculated for the following four typical operational conditions:

- Case (IN) - initial condition: 5-ft of waste overlying 1-ft of protective cover and the rest of the liner system.
- Case (INTERM) - intermediate condition: 15-ft of waste overlying 1-ft of protective cover and the rest of the liner system.
- Case (FNC) - final condition prior to installation of final cover: 23-ft of waste overlying 1-ft of protective cover and the rest of the liner system.
- Case (FC) - final condition after installation of final cover: final cover system on top of 23-ft of waste overlying 1-ft of protective cover and the rest of the liner system.

It should be noted that the leachate generation rates from the liner system on the side slopes would be lower compared to the leachate generation rates for the floor liner system because of steeper side slopes. Therefore, no analysis was done for the sideslope liner system and the transmissivity for the sideslope liner system was conservatively assumed to be similar to the floor liner system.

The proposed liner system on the base of the landfill for the RCRA Subtitle C Cell will consist of the following components, from top to bottom:

- 1-ft thick protective cover;
- upper geocomposite drainage layer (leachate collection system);
- upper 80-mil thick high density polyethylene (HDPE) geomembrane liner (primary liner);
- lower geocomposite drainage layer (leak detection system);
- lower 80-mil thick HDPE geomembrane liner (secondary liner); and
- geosynthetic clay liner.

It is noted that in addition to the base liner system components described above, a 1-ft thick layer of compacted clay will be installed beneath the geosynthetic clay liner. Because conclusions regarding leachate generation rates, design of leachate drainage layers, and maximum leachate head are not changed by the presence of additional soil layers below the geosynthetic clay liner, for simplicity, the lower-most layer of compacted clay was not included in the HELP model calculations.

The proposed final cover system for the RCRA Subtitle C Cell will consist of the following components, from top to bottom:

- 6-in. thick top soil;
- 1-ft thick cover soil;
- geocomposite drainage layer;
- 40-mil thick linear low density polyethylene (LLDPE) geomembrane liner;
- geosynthetic clay liner (GCL); and
- geocomposite gas vent layer.

4. PARAMETERS USED IN ANALYSIS

The *HELP* model requires the input of daily weather data, vegetation data, soils data, and landfill design data. The input data are described in this section and summarized on the *HELP* model output presented in Appendix 1.

4.1 Weather Data

4.1.1 Precipitation and Temperature Data

Thirty years of synthetic weather data were generated for the RCRA Subtitle C Cell using climatic data for nearby Galveston, Texas. Additionally, the peak daily rainfall from the synthetically generated precipitation record (5.43 in.) was manually increased to model the impact of the 25-year, 24-hour storm event on peak hydraulic head. The 25-year, 24-hour storm intensity for the site was estimated to be 10.3 in. based on the average of values reported for Galveston County in a Technical Paper, TR-55 (USDA, 1986). Although active waste filling of the RCRA Subtitle C Cell is anticipated to be completed within a relatively short time (about a year), thirty years of simulations were performed in order to ensure adequate performance of the leachate collection system under a variety of possible climatic conditions.

4.1.2 Evapotranspiration and Solar Radiation

Synthetic data was generated for the evapotranspiration and solar radiation data as well. As with the precipitation and temperature data, synthetic data for Galveston, Texas was generated for the analysis. Vegetation was assumed only on the final cover system (Case FC). The final cover system was assumed to have good vegetation with a maximum LAI of 3.5. An evaporative zone depth of 18 in. was selected to equal the thickness of the erosion layer above the composite barrier. For the initial and intermediate conditions, an evaporative zone depth of 10 in. was selected.

4.2 Materials Data

4.2.1 Top Soil for Final Cover System

The top soil of the final cover system was modeled as a vertical percolation layer with *HELP* material texture 11 (representative of low density CL cover soil).

4.2.2 Cover Soil for Final Cover System

The cover soil of the final cover system was modeled as a vertical percolation layer with *HELP* material texture 26 (representative of moderately compacted CL soil).

4.2.3 Geosynthetic Drainage Layer for Final Cover System

The geocomposite drainage layer was modeled as a lateral drainage layer with *HELP* material texture 20 (representative of 0.2-in. thick geonet drainage layer). The design hydraulic conductivity (k) of the drainage layer was calculated from the final-condition scenario (Case FC) by varying k until the peak daily average head on the geomembrane liner on the final cover was approximately equal to the thickness of erosion layer (18 in.). This was done to allow maximum head building up on the final cover liner, resulting in a conservatively high estimate of the amount of water infiltrating into the landfill.

A special case of the final cover condition (Case FC-S) was also run to determine the hydraulic conductivity required to maintain a peak daily average head no greater than the thickness of the geocomposite drainage layer. It is noted that this case is not used for the determination of leachate generation, but rather for the calculation of the minimum required transmissivity of the geosynthetic drainage layer in the final cover system.

4.2.4 Geomembrane Barrier for Final Cover System

The geomembrane barrier of the final cover system was modeled as a flexible membrane liner with *HELP* material texture 36 (representative of LLDPE geomembrane), installation condition = poor, pinhole defect frequency = 2 per acre, and installation defect frequency = 2 per acre. This hole frequency is an assumption for design purposes only to result in a conservatively high amount of infiltration through the final cover, and is not a reflection of the expected or allowable hole density. For the special analysis case FC-S, the geomembrane installation quality was assumed to be perfect. For the design of geocomposite drainage layers overlying a geomembrane, this is a conservative design assumption which maximizes flow in the drainage layer by minimizing infiltration through the geomembrane.

4.2.5 Geosynthetic Clay Liner for Final cover system

The Geosynthetic Clay Liner (GCL) was modeled as a vertical percolation layer with *HELP* material texture 17 having a saturated hydraulic conductivity of 5×10^{-9} cm/s.

4.2.6 Geosynthetic Gas Vent Layer for Final Cover System

The geocomposite gas vent layer was modeled as a vertical percolation layer with *HELP* material texture 20 (representative of 0.2-in. thick geonet drainage layer).

4.2.7 Waste

The waste to be disposed of at the RCRA Subtitle C Cell will consist primarily of solidified sludge pit and oil pit material, which will be solidified in situ and excavated prior to placement in the cell. No default *HELP* material texture is available for the type of waste to be disposed of in the RCRA Subtitle C Cell. Furthermore, no specific properties were found for this type of waste

from a literature search and from a Geosyntec company wide technical data search. Instead, based on the available laboratory data for the solidified waste material, it was assumed that the waste properties would best be approximated as a silty sand (SM) type of material with a hydraulic conductivity of approximately 4×10^{-3} cm/s. Accordingly, the waste layer was modeled as a vertical percolation layer with the average properties of *HELP* material texture 4 (representative of SM type soil) having a hydraulic conductivity of 4×10^{-3} cm/s.

For cases IN, INTERM, and FNC, the top 12" of waste material was modeled with an initial moisture content corresponding to the approximate expected as-compacted moisture content to simulate a layer of freshly placed waste. The remainder of the waste material was modeled with an initial moisture content representative of waste material which has achieved steady-state moisture conditions (this process is expected to occur relatively quickly, within days to weeks after the placement of a given quantity of waste).

Because the leachate collection corridor chimney drains terminate 6 inches above the top of the protective cover material, and are hydraulically connected to the waste material, some leachate is expected to flow directly from the waste material into the leachate collection corridor. To model the process of leachate moving laterally through the waste material into the chimney drain, the bottom 12" of waste material was modeled as a lateral drainage layer with *HELP* material texture 4 (representative of SM type soil) having a hydraulic conductivity of 4×10^{-3} cm/s.

4.2.8 Protective Cover Layer for Liner System

It is anticipated that the protective cover layer will be constructed of impacted site soils. Based on available data and Geosyntec experience on nearby sites, the site soils are assumed to be generally classified as a combination of low-plasticity clays and high-plasticity clays. For calculation purposes, this layer was modeled as a vertical percolation layer with properties in-between *HELP* material texture 26 (representative of moderately compacted CL soil) and *HELP* material texture 28 (representative of moderately compacted CH soil)

4.2.9 Geosynthetic Drainage Layers for Liner System

The leachate collection and leak detection systems consist of geocomposite drainage layers responsible for lateral drainage of percolating leachate. The geocomposite drainage layers of the liner system were modeled as a lateral drainage layer with *HELP* material texture 20 (representative of 0.2-in. thick geonet drainage layer). The design hydraulic conductivity (k) of the drainage layer was calculated for each operation case by varying k until the peak daily average head on the geomembrane liner was approximately equal to the thickness of drainage layer. However, the minimum design hydraulic conductivity used in the calculations was 0.01 cm/s. This procedure is conservative because the drainage layer thickness is much less than the

regulated maximum head of 12 in. and because the peak daily average head is typically much greater than the annual average head.

4.2.10 Geomembrane Liners for Liner System

The landfill liner on the base of the landfill consists of two geomembrane liners: upper and lower liners. The geomembrane layers were modeled as flexible membrane liners with *HELP* material texture 35 (representative of HDPE geomembrane). The geomembrane was assumed to be free of defects and the installation quality was assumed to be perfect; for the design of the geocomposite drainage layer (leachate collection system) overlying a geomembrane, this is a conservative design assumption which maximizes flow in the drainage layer by minimizing infiltration through the geomembrane. This is an assumption for design purposes only and is not a reflection of the expected or allowable geomembrane installation quality or hole frequency.

4.2.11 Geosynthetic Clay Liner for Liner system

The Geosynthetic Clay Liner (GCL) of the liner system was modeled as a vertical percolation layer with *HELP* material texture 17 having a saturated hydraulic conductivity of 5×10^{-9} cm/s.

4.3 Landfill Design Data

The design data required by the *HELP* model consists of: (i) the slope and slope length of the surface of the top layer; (ii) the slope and slope length of lateral drainage layers (geosynthetic drainage component) in the final cover system and liner system; and (iii) the percentage of runoff that can be directed off of the landfill whether as clean surface water or as leachate running off the waste to a storm water storage area. Because stormwater runoff from the RCRA Subtitle C Cell can be directed away from the leachate system as contact water, it was assumed that the potential runoff for design calculations is 100%. The actual percentage runoff is calculated by the *HELP* model based on surface slope, slope length, material texture, and vegetation. The landfill design parameters used in the analysis are presented on Figure 1 for the four scenarios evaluated.

5. RESULTS OF ANALYSIS

The results of the *HELP* model analysis are summarized below. The output files are presented in Appendix 1.

5.1 Estimated Leachate Generation/Collection Rates

The estimated leachate generation rates are shown in Table 1. The leachate generation rates shown correspond to the lateral drainage collected from the leachate collection layer and the bottom 12" of waste material (which has direct access to the chimney drain leading to the leachate collection corridor).

The maximum leachate generation rate was for the initial condition Case I that has the thinnest layer of waste (5 ft). For the initial condition (Case IN), the maximum daily leachate collection rate is calculated to be 1,533 gallons per acre per day (gpad), and the average annual collection rate is calculated to be 1,037 gpad.

For the intermediate condition (Case INTERM), the calculated maximum daily and average annual leachate collection rates on the landfill floor are 1,497 gpad and 1,032 gpad, respectively.

The average leachate collection rate after closure of the landfill (Cases FNC and FC) is expected to decrease over time as leachate is drained from the waste. The maximum daily and average annual leachate collection rates on the landfill floor for final closure conditions are calculated to be about 1,175 gpad and 146 gpad, respectively, prior to placement of final cover, and 0.5 gpad and 0.1 gpad, respectively, after placement of final cover.

As mentioned earlier, the leachate collection rate and maximum leachate head on the side slope liner system would be lower compared to that of the floor liner system due to the steeper side slopes. Since no analysis was done for the side slope liner system, it was conservatively assumed for design purposes that the leachate collection rate and maximum leachate head on the side slope liner system would be similar to the floor liner system.

The peak daily and average annual leachate volumes for each subcell were calculated based on the tributary area for each subcell and the estimated peak daily and average annual leachate generation/collection rates for each case and are shown in Table 2.

5.2 Drainage Layer Design Hydraulic Conductivity and Transmissivity

The design hydraulic conductivity of the leachate drainage layer was calculated for each operation case by varying hydraulic conductivity until the peak daily average head on the geomembrane liner was approximately equal to the thickness of the geosynthetic drainage layer. However, the minimum hydraulic conductivity of the leachate drainage layer was assumed to be

0.01 cm/s. The transmissivity was calculated by multiplying the drainage layer hydraulic conductivity by the drainage layer thickness. Results for each case are presented in Table 3. These represent the design transmissivity values. Refer to the Leachate Collection System and Leak Detection System Drainage Layer Design calculation package for an evaluation of the required in-service transmissivity and resulting drainage layer specifications.

5.3 Head of Leachate over Composite Barriers

The hydraulic heads on top of the geomembranes of the composite barrier systems calculated using the predicted *HELP* model are summarized in Table 4. The calculated annual average heads on the upper geomembrane of the liner system range from 0.004 to 0.136 in., while the annual average head on the lower geomembrane is zero.

Considering all cases analyzed, the maximum calculated peak daily average head is 0.195 in. on the upper geomembrane and zero on the lower geomembrane. The maximum calculated peak daily average head on the geomembrane is less than the allowable hydraulic head of 30 cm (12 in.). The calculated peak daily average heads are less than or equal to the thickness of a geocomposite drainage layer (0.2 in.) on the landfill floor and sideslope. Thus, the flow is predicted to occur within the drainage layer only. Based on the above, the geosynthetic drainage layer is considered adequate in minimizing liquid head on top of the liner.

6. SUMMARY AND CONCLUSIONS

The *HELP* model was used to estimate the design leachate collection rates in the geosynthetic drainage layer, calculate the design in-plane hydraulic conductivity and transmissivity of the geosynthetic drainage layer, and calculate the maximum leachate head on the liner system. Parameters for various design and operational conditions that characterize the site over time were input into the model.

Results from the *HELP* model show that maximum peak daily leachate collection rate will be 1,533 gpad, while the maximum annual average leachate collection rate will be 1,037 gpad (both during initial condition). For all operational cases, the calculated head of leachate on the liner is less than the regulatory maximum of 30 cm (12 in.).

7. REFERENCES

Schroeder, P.R., Dozier, T.S., Zappi, P.A., McEnroe, B.M., Sjostrom, J.W., and Peyton, R.L., "The Hydrologic Evaluation of Landfill Performance (*HELP*) Model Engineering Documentation for Version 3," U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C., Report No. EPA/600/R-94/168b, 1994a, 116 p.

Schroeder, P.R., Lloyd, C.M., and Zappi, P.A., "The Hydrologic Evaluation of Landfill Performance (*HELP*) Model, User's Guide for Version 3," U.S. Environmental Protection Agency, Office of Research and Development Washington, D.C., Report No. EPA/600/R-94/168a, 1994b.

USDA (United States Department of Agriculture, 1986), "TR-55: Urban Hydrology for Small Watersheds", USDA Natural Resources Conservation Service, Conservation Engineering Division, Report No. 210-VI-TR-55, Second Ed, 164p.

TABLES

TABLE 1. LEACHATE GENERATION RATES

Case	Average Annual		Peak Daily Average	
	(in./yr)	(gpad)	(in./day)	(gpad)
IN	13.941	1037.1	0.0565	1533.4
INTERM	13.882	1032.8	0.0551	1497.3
FNC	13.434	999.4	0.0549	1490.5
FC	0.00117	0.1	0.00002	0.5

Note: gpad = gallons per acre per day

TABLE 2. CALCULATED LEACHATE VOLUMES

Subcell	Tributary Area	**Calculated Peak Daily Leachate Volume**							
		Case IN		Case INTERM		Case FNC		Case FC	
	(acres)	(in.)	(gallons)	(in.)	(gallons)	(in.)	(gallons)	(in.)	(gallons)
1	10.7	0.0565	16,407	0.0551	16,021	0.0549	15,948	0.00002	5.8
2	6.2	0.0565	9,507	0.0551	9,283	0.0549	9,241	0.00002	3.4
3/4	14.4	0.0565	22,081	0.0551	21,561	0.0549	21,463	0.00002	7.8

Subcell	Tributary Area	**Calculated Annual Leachate Volume**							
		Case IN		Case INTERM		Case FNC		Case FC	
	(acres)	(in.)	(gallons)	(in.)	(gallons)	(in.)	(gallons)	(in.)	(gallons)
1	10.7	13.94	4,050,474	13.88	4,033,500	13.43	3,903,295	0.00117	340
2	6.2	13.94	2,347,003	13.88	2,337,168	13.43	2,261,722	0.00117	197
3/4	14.4	13.94	5,451,105	13.88	5,428,261	13.43	5,253,033	0.00117	457

TABLE 3. LIQUID COLLECTION LAYER DESIGN HYDRAULIC CONDUCTIVITY AND TRANSMISSIVITY

Case	Design Hydraulic Conductivity (cm/s)	Liquid Drainage Layer Thickness (in.)	Design Transmissivity (m^2/s)
IN	3.7	0.20	1.9×10^{-4}
INTERM	3.7	0.20	1.9×10^{-4}
FNC	3.7	0.20	1.9×10^{-4}
FC	0.01	0.20	5.1×10^{-7}
FC-S	0.73	0.20	3.7×10^{-5}

Notes:

1. Design hydraulic conductivities and transmissivities shown here are not specifications for the leachate drainage layer. Specifications for the leachate drainage layer, after accounting for in-service effects, are presented in the Leachate Collection System and Leak Detection System Drainage Layer Design calculation package.
2. Design transmissivity = design hydraulic conductivity ´ drainage layer thickness.
3. Case IN, INTERM, FNC, and FC values refer to design transmissivities of the leachate collection layer in the liner system.
4. Case FC-S values refer to the design transmissivity of the liquid collection layer in the final cover system.

TABLE 4. CALCULATED LEACHATE HEAD ON TOP OF GEOMEMBRANE

Case	Head on Top of Final Cover Geomembrane (in.)			Head on Top of Upper Liner Geomembrane (in.)			Head on Top of Lower Liner Geomembrane (in.)		
	Annual Avg.	Peak Daily Avg.	Peak Daily Max.	Annual Avg.	Peak Daily Avg.	Peak Daily Max.	Annual Avg.	Peak Daily Avg.	Peak Daily Max.
IN[1]	--	--	--	0.136	0.195	1.192	0	0	0.001
INTERM[1]	--	--	--	0.136	0.195	1.192	0	0	0.001
FNC[1]	--	--	--	0.131	0.195	1.192	0	0	0.001
FC[2]	0.235	17.477	25.846	0.004	0.027	0.442	0	0	0
FC-S[1]	0.016	0.197	0.390	0.003	0.027	0.443	0	0	0

Notes:

1. Values calculated for Case I, INT, FNC, and FC-S are based on a back-calculated hydraulic conductivity for the geocomposite drainage layers such that they yield a maximum peak daily average head of 0.2 in. from the *HELP* analysis.
2. Values calculated for Case FC (final cover condition) are based on a minimum geocomposite hydraulic conductivity of 0.01 cm/s for drainage layers in the liner system and a peak daily average head over the final cover system approximately equal to the thickness of the erosion layer (18 in.).

FIGURES

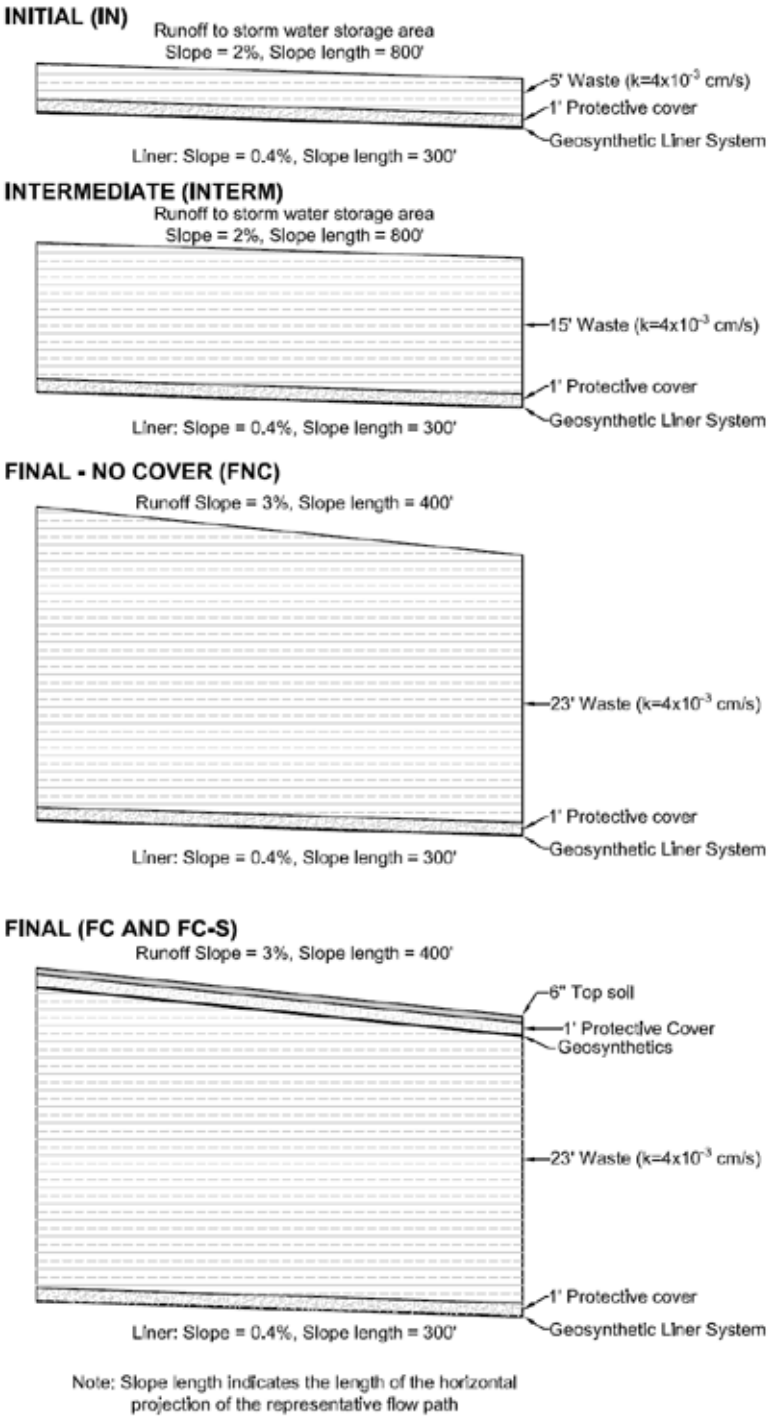


Figure 1. Landfill Design Parameters used in *HELP* Model Analysis.

APPENDIX 1

HELP MODEL COMPUTER PROGRAM OUTPUT FILES

Written by: **A. Brown** Date: **7/28/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT** Project: **Malone Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Case IN: Initial Condition

```
**************************************************************************
**************************************************************************
**                                                                      **
**                                                                      **
**             HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE             **
**               HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)             **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                **
**                   USAE WATERWAYS EXPERIMENT STATION                  **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY           **
**                                                                      **
**                                                                      **
**************************************************************************
**************************************************************************



PRECIPITATION DATA FILE:    \RAIN25.D4
TEMPERATURE DATA FILE:      \TEMP.D7
SOLAR RADIATION DATA FILE:  \SOLAR.D13
EVAPOTRANSPIRATION DATA:    \ET_BARE.D11
SOIL AND DESIGN DATA FILE:  \IN_M.D10
OUTPUT DATA FILE:           \IN_M.OUT


TIME:   9: 0     DATE:   8/29/2014



**************************************************************************

     TITLE:  Malone Superfund Site - Initial Case

**************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                               LAYER  1
                               --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
          THICKNESS                     =     12.00   INCHES
          POROSITY                      =      0.4370 VOL/VOL
          FIELD CAPACITY                =      0.1050 VOL/VOL
          WILTING POINT                 =      0.0470 VOL/VOL
          INITIAL SOIL WATER CONTENT    =      0.4310 VOL/VOL
          EFFECTIVE SAT. HYD. COND.     =  0.400000019000E-02 CM/SEC



                               LAYER  2
                               --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
          THICKNESS                     =     36.00   INCHES
          POROSITY                      =      0.4370 VOL/VOL
          FIELD CAPACITY                =      0.1050 VOL/VOL
          WILTING POINT                 =      0.0470 VOL/VOL
          INITIAL SOIL WATER CONTENT    =      0.1679 VOL/VOL
          EFFECTIVE SAT. HYD. COND.     =  0.400000019000E-02 CM/SEC



                               LAYER  3
                               --------

                    TYPE 2 - LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER   0
          THICKNESS                     =     12.00   INCHES
          POROSITY                      =      0.4370 VOL/VOL
          FIELD CAPACITY                =      0.1050 VOL/VOL
          WILTING POINT                 =      0.0470 VOL/VOL
          INITIAL SOIL WATER CONTENT    =      0.1050 VOL/VOL
          EFFECTIVE SAT. HYD. COND.     =  0.400000019000E-02 CM/SEC
          SLOPE                         =      0.40   PERCENT
          DRAINAGE LENGTH               =    300.0    FEET



                               LAYER  4
                               --------

                    TYPE 3 - BARRIER SOIL LINER
                         MATERIAL TEXTURE NUMBER   0
          THICKNESS                     =      1.00   INCHES
          POROSITY                      =      0.4490 VOL/VOL
          FIELD CAPACITY                =      0.4020 VOL/VOL
          WILTING POINT                 =      0.2940 VOL/VOL
          INITIAL SOIL WATER CONTENT    =      0.4490 VOL/VOL
          EFFECTIVE SAT. HYD. COND.     =  0.160000002000E-05 CM/SEC



                               LAYER  5
                               --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
          THICKNESS                     =     11.00   INCHES
          POROSITY                      =      0.4490 VOL/VOL
          FIELD CAPACITY                =      0.4020 VOL/VOL
          WILTING POINT                 =      0.2940 VOL/VOL
          INITIAL SOIL WATER CONTENT    =      0.4490 VOL/VOL
          EFFECTIVE SAT. HYD. COND.     =  0.160000002000E-05 CM/SEC



                               LAYER  6
                               --------

                    TYPE 2 - LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER   0
          THICKNESS                     =      0.20   INCHES
          POROSITY                      =      0.8500 VOL/VOL
          FIELD CAPACITY                =      0.0100 VOL/VOL
          WILTING POINT                 =      0.0050 VOL/VOL
          INITIAL SOIL WATER CONTENT    =      0.8273 VOL/VOL
          EFFECTIVE SAT. HYD. COND.     =   3.70000005000      CM/SEC
          SLOPE                         =      0.40   PERCENT
          DRAINAGE LENGTH               =    300.0    FEET



                               LAYER  7
                               --------

                    TYPE 4 - FLEXIBLE MEMBRANE LINER
                      MATERIAL TEXTURE NUMBER  35
          THICKNESS                     =      0.08   INCHES
          POROSITY                      =      0.0000 VOL/VOL
          FIELD CAPACITY                =      0.0000 VOL/VOL
          WILTING POINT                 =      0.0000 VOL/VOL
          INITIAL SOIL WATER CONTENT    =      0.0000 VOL/VOL
          EFFECTIVE SAT. HYD. COND.     =  0.199999996000E-12 CM/SEC
          FML PINHOLE DENSITY           =      0.00   HOLES/ACRE
          FML INSTALLATION DEFECTS      =      0.00   HOLES/ACRE
          FML PLACEMENT QUALITY         =  1 - PERFECT



                               LAYER  8
                               --------

                    TYPE 2 - LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER   0
          THICKNESS                     =      0.20   INCHES
          POROSITY                      =      0.8500 VOL/VOL
          FIELD CAPACITY                =      0.0100 VOL/VOL
          WILTING POINT                 =      0.0050 VOL/VOL
          INITIAL SOIL WATER CONTENT    =      0.0100 VOL/VOL
          EFFECTIVE SAT. HYD. COND.     =   3.70000005000      CM/SEC
          SLOPE                         =      0.40   PERCENT
          DRAINAGE LENGTH               =    300.0    FEET



                               LAYER  9
                               --------

                    TYPE 4 - FLEXIBLE MEMBRANE LINER
                      MATERIAL TEXTURE NUMBER  35
          THICKNESS                     =      0.08   INCHES
          POROSITY                      =      0.0000 VOL/VOL
          FIELD CAPACITY                =      0.0000 VOL/VOL
          WILTING POINT                 =      0.0000 VOL/VOL
          INITIAL SOIL WATER CONTENT    =      0.0000 VOL/VOL
          EFFECTIVE SAT. HYD. COND.     =  0.199999996000E-12 CM/SEC
          FML PINHOLE DENSITY           =      0.00   HOLES/ACRE
          FML INSTALLATION DEFECTS      =      0.00   HOLES/ACRE
          FML PLACEMENT QUALITY         =  1 - PERFECT



                               LAYER 10
                               --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  17
          THICKNESS                     =      0.20   INCHES
          POROSITY                      =      0.7500 VOL/VOL
          FIELD CAPACITY                =      0.7470 VOL/VOL
          WILTING POINT                 =      0.4000 VOL/VOL
```

```
          INITIAL SOIL WATER CONTENT  =      0.6480 VOL/VOL
          EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC



                  GENERAL DESIGN AND EVAPORATIVE ZONE DATA
                  ---------------------------------------

        NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
                 SOIL DATA BASE USING SOIL TEXTURE # 4 WITH BARE
                 GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
                 A SLOPE LENGTH OF  800. FEET.

      SCS RUNOFF CURVE NUMBER             =     80.10
      FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
      AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
      EVAPORATIVE ZONE DEPTH              =     10.0    INCHES
      INITIAL WATER IN EVAPORATIVE ZONE   =      4.310  INCHES
      UPPER LIMIT OF EVAPORATIVE STORAGE  =      4.370  INCHES
      LOWER LIMIT OF EVAPORATIVE STORAGE  =      0.470  INCHES
      INITIAL SNOW WATER                  =      0.000  INCHES
      INITIAL WATER IN LAYER MATERIALS    =     18.161  INCHES
      TOTAL INITIAL WATER                 =     18.161  INCHES
      TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR



                  EVAPOTRANSPIRATION AND WEATHER DATA
                  -----------------------------------

        NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                 GALVESTON             TEXAS

            STATION LATITUDE                      =  29.18 DEGREES
            MAXIMUM LEAF AREA INDEX               =   0.00
            START OF GROWING SEASON (JULIAN DATE) =      0
            END OF GROWING SEASON (JULIAN DATE)   =    367
            EVAPORATIVE ZONE DEPTH                =  10.0  INCHES
            AVERAGE ANNUAL WIND SPEED             =  11.00 MPH
            AVERAGE 1ST QUARTER RELATIVE HUMIDITY =  80.00 %
            AVERAGE 2ND QUARTER RELATIVE HUMIDITY =  79.00 %
            AVERAGE 3RD QUARTER RELATIVE HUMIDITY =  76.00 %
            AVERAGE 4TH QUARTER RELATIVE HUMIDITY =  77.00 %


        NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
                 COEFFICIENTS FOR    GALVESTON           TEXAS

                 NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

     JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
     -------     -------     -------     -------     -------     -------
       2.96        2.34        2.10        2.62        3.30        3.48
       3.77        4.40        5.82        2.60        3.23        3.62


        NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                 COEFFICIENTS FOR    GALVESTON           TEXAS

             NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

     JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
     -------     -------     -------     -------     -------     -------
      53.60       55.60       61.40       69.10       75.70       81.20
      83.20       83.20       80.00       72.70       63.00       56.80


        NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                 COEFFICIENTS FOR    GALVESTON           TEXAS
                   AND STATION LATITUDE  =  29.18 DEGREES



********************************************************************************

        AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH   30
--------------------------------------------------------------------------------

                        JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                        -------  -------  -------  -------  -------  -------
  PRECIPITATION
  -------------
    TOTALS                2.85     2.10     1.99     2.39     4.18     3.87
                          3.86     3.62     5.50     2.38     3.02     3.48

    STD. DEVIATIONS       1.36     1.49     1.17     1.76     2.73     2.48
                          1.98     1.77     2.73     1.37     1.96     1.82

  RUNOFF
  ------
    TOTALS                0.039    0.009    0.011    0.060    0.189    0.266
                          0.111    0.063    0.336    0.044    0.076    0.078

    STD. DEVIATIONS       0.082    0.037    0.045    0.112    0.343    0.991
                          0.163    0.137    0.428    0.120    0.145    0.165

  EVAPOTRANSPIRATION
  ------------------
    TOTALS                1.783    1.642    1.672    1.570    2.352    2.257
                          2.496    2.522    2.556    1.719    1.622    1.763

    STD. DEVIATIONS       0.526    0.681    0.783    0.879    1.178    1.111
                          1.044    0.977    0.812    0.822    0.652    0.522

  LATERAL DRAINAGE COLLECTED FROM LAYER  3
  -----------------------------------------
    TOTALS                0.0024   0.0010   0.0002   0.0003   0.0020   0.0029
                          0.0013   0.0016   0.0036   0.0036   0.0017   0.0020

    STD. DEVIATIONS       0.0038   0.0022   0.0005   0.0011   0.0039   0.0042
                          0.0021   0.0034   0.0047   0.0058   0.0029   0.0028

  PERCOLATION/LEAKAGE THROUGH LAYER  4
  -------------------------------------
    TOTALS                1.3134   0.8460   0.6405   0.5321   1.1489   1.4664
                          1.1700   1.1942   1.6168   1.6503   1.1641   1.2810

    STD. DEVIATIONS       1.0563   0.7582   0.3649   0.4790   1.0938   1.1463
                          0.6821   0.9076   1.1194   1.3594   0.8587   0.8957

  LATERAL DRAINAGE COLLECTED FROM LAYER  6
  -----------------------------------------
    TOTALS                1.2411   1.1118   1.1478   0.8707   0.8892   1.1056
                          1.2009   1.2105   1.1849   1.4135   1.3011   1.2410

    STD. DEVIATIONS       0.5565   0.5348   0.5302   0.5507   0.5517   0.5491
                          0.5060   0.5387   0.4266   0.4813   0.4884   0.4862

  PERCOLATION/LEAKAGE THROUGH LAYER  7
  -------------------------------------
    TOTALS                0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS       0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  LATERAL DRAINAGE COLLECTED FROM LAYER  8
  -----------------------------------------
    TOTALS                0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS       0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  PERCOLATION/LEAKAGE THROUGH LAYER  9
  -------------------------------------
    TOTALS                0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS       0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  PERCOLATION/LEAKAGE THROUGH LAYER 10
  ------------------------------------
    TOTALS                0.0001   0.0001   0.0001   0.0001   0.0001   0.0001
                          0.0001   0.0001   0.0001   0.0001   0.0001   0.0001

    STD. DEVIATIONS       0.0002   0.0002   0.0002   0.0001   0.0001   0.0001
                          0.0001   0.0001   0.0001   0.0001   0.0001   0.0001


--------------------------------------------------------------------------------
            AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
--------------------------------------------------------------------------------


  DAILY AVERAGE HEAD ON TOP OF LAYER  4
  -------------------------------------
    AVERAGES              0.2618   0.1219   0.0207   0.0336   0.2137   0.3218
                          0.1354   0.1661   0.4012   0.3764   0.1865   0.2158

    STD. DEVIATIONS       0.4043   0.2559   0.0517   0.1189   0.4156   0.4555
                          0.2190   0.3607   0.5113   0.6011   0.3147   0.2994

  DAILY AVERAGE HEAD ON TOP OF LAYER  7
  -------------------------------------
    AVERAGES              0.1431   0.1406   0.1324   0.1038   0.1026   0.1318
                          0.1385   0.1396   0.1412   0.1630   0.1551   0.1431

    STD. DEVIATIONS       0.0642   0.0674   0.0612   0.0656   0.0636   0.0654
                          0.0584   0.0621   0.0508   0.0555   0.0582   0.0561

  DAILY AVERAGE HEAD ON TOP OF LAYER  9
  -------------------------------------
    AVERAGES              0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS       0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

********************************************************************************
```

Written by: **A. Brown** Date: **7/28/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT** Project: **Malone Superfund Site** Project No.: **TXL0299** Phase No.: **02**

```
*******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH   30
-------------------------------------------------------------------------------
                                  INCHES            CU. FEET       PERCENT
                              -------------------  -------------  ---------
 PRECIPITATION                 39.24    (   6.898)    142436.4     100.00

 RUNOFF                         1.282   (  1.1280)      4655.29      3.268

 EVAPOTRANSPIRATION            23.953   (  3.4467)     86949.71     61.045

 LATERAL DRAINAGE COLLECTED     0.02260 (  0.01183)       82.032    0.05759
   FROM LAYER  3

 PERCOLATION/LEAKAGE THROUGH   14.02357 (  3.43298)    50905.578    35.73917
   LAYER  4

 AVERAGE HEAD ON TOP            0.205 (    0.106)
   OF LAYER  4

 LATERAL DRAINAGE COLLECTED    13.91807 (  2.86279)    50522.605   35.47030
   FROM LAYER  6

 PERCOLATION/LEAKAGE THROUGH    0.00000 (  0.00000)        0.017     0.00001
   LAYER  7

 AVERAGE HEAD ON TOP            0.136 (    0.028)
   OF LAYER  7

 LATERAL DRAINAGE COLLECTED     0.00000 (  0.00000)        0.008    0.00001
   FROM LAYER  8

 PERCOLATION/LEAKAGE THROUGH    0.00000 (  0.00000)        0.009     0.00001
   LAYER  9

 AVERAGE HEAD ON TOP            0.000 (    0.000)
   OF LAYER  9

 PERCOLATION/LEAKAGE THROUGH    0.00100 (  0.00156)        3.634     0.00255
   LAYER 10

 CHANGE IN WATER STORAGE        0.061   (  3.1973)       223.13      0.157
*******************************************************************************


*******************************************************************************

              PEAK DAILY VALUES FOR YEARS    1 THROUGH   30
   ---------------------------------------------------------------------
                                              (INCHES)      (CU. FT.)
                                             ----------   -------------
      PRECIPITATION                           10.30        37389.000

      RUNOFF                                   5.440       19748.0527

      DRAINAGE COLLECTED FROM LAYER  3         0.00205         7.43549

      PERCOLATION/LEAKAGE THROUGH LAYER  4     0.393190     1427.27808

      AVERAGE HEAD ON TOP OF LAYER  4          6.225

      MAXIMUM HEAD ON TOP OF LAYER  4          8.131

      LOCATION OF MAXIMUM HEAD IN LAYER  3
            (DISTANCE FROM DRAIN)             120.0 FEET

      DRAINAGE COLLECTED FROM LAYER  6         0.05442       197.56023

      PERCOLATION/LEAKAGE THROUGH LAYER  7     0.000000        0.00006

      AVERAGE HEAD ON TOP OF LAYER  7          0.195

      MAXIMUM HEAD ON TOP OF LAYER  7          1.192

      LOCATION OF MAXIMUM HEAD IN LAYER  6
            (DISTANCE FROM DRAIN)              0.0 FEET

      DRAINAGE COLLECTED FROM LAYER  8         0.00000         0.00004

      PERCOLATION/LEAKAGE THROUGH LAYER  9     0.000000        0.00002

      AVERAGE HEAD ON TOP OF LAYER  9          0.000

      MAXIMUM HEAD ON TOP OF LAYER  9          0.001

      LOCATION OF MAXIMUM HEAD IN LAYER  8
            (DISTANCE FROM DRAIN)              0.0 FEET

      PERCOLATION/LEAKAGE THROUGH LAYER 10     0.000038        0.13664

      SNOW WATER                               1.71         6208.4434


      MAXIMUM VEG. SOIL WATER (VOL/VOL)                0.4310

      MINIMUM VEG. SOIL WATER (VOL/VOL)                0.0470
```

```
      ***  Maximum heads are computed using McEnroe's equations.  ***

           Reference:  Maximum Saturated Depth over Landfill Liner
                       by Bruce M. McEnroe, University of Kansas
                       ASCE Journal of Environmental Engineering
                       Vol. 119, No. 2, March 1993, pp. 262-270.

*******************************************************************************

*******************************************************************************

                  FINAL WATER STORAGE AT END OF YEAR   30
   ---------------------------------------------------------------------
                   LAYER        (INCHES)       (VOL/VOL)
                   -----        --------       ---------
                     1            2.0193         0.1683

                     2            7.4917         0.2081

                     3            1.6743         0.1395

                     4            0.4490         0.4490

                     5            8.1040         0.7367

                     6            0.1655         0.8273

                     7            0.0000         0.0000

                     8            0.0020         0.0100

                     9            0.0000         0.0000

                    10            0.0996         0.4982

                 SNOW WATER       0.000

*******************************************************************************
*******************************************************************************
```

Case INTERM: Intermediate Condition

```
**************************************************************************
**************************************************************************
**                                                                      **
**                                                                      **
**             HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE             **
**               HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)             **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                **
**                   USAE WATERWAYS EXPERIMENT STATION                  **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY           **
**                                                                      **
**                                                                      **
**************************************************************************
**************************************************************************



PRECIPITATION DATA FILE:    \RAIN25.D4
TEMPERATURE DATA FILE:      \TEMP.D7
SOLAR RADIATION DATA FILE:  \SOLAR.D13
EVAPOTRANSPIRATION DATA:    \ET_BARE.D11
SOIL AND DESIGN DATA FILE:  \INTERM.D10
OUTPUT DATA FILE:           \INTERM.OUT


TIME:   8:59     DATE:   8/29/2014



**************************************************************************

     TITLE:  Malone Superfund Site - Intermediate Case

**************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                               LAYER  1
                               --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =     12.00   INCHES
          POROSITY                     =      0.4370 VOL/VOL
          FIELD CAPACITY               =      0.1050 VOL/VOL
          WILTING POINT                =      0.0470 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.4310 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.400000019000E-02 CM/SEC



                               LAYER  2
                               --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =    156.00   INCHES
          POROSITY                     =      0.4370 VOL/VOL
          FIELD CAPACITY               =      0.1050 VOL/VOL
          WILTING POINT                =      0.0470 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.1745 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.400000019000E-02 CM/SEC



                               LAYER  3
                               --------

                    TYPE 2 - LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =     12.00   INCHES
          POROSITY                     =      0.4370 VOL/VOL
          FIELD CAPACITY               =      0.1050 VOL/VOL
          WILTING POINT                =      0.0470 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.1050 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.400000019000E-02 CM/SEC
          SLOPE                        =      0.40   PERCENT
          DRAINAGE LENGTH              =    300.0    FEET



                               LAYER  4
                               --------

                    TYPE 3 - BARRIER SOIL LINER
                         MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =      1.00   INCHES
          POROSITY                     =      0.4490 VOL/VOL
          FIELD CAPACITY               =      0.4020 VOL/VOL
          WILTING POINT                =      0.2940 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.4490 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.160000002000E-05 CM/SEC



                               LAYER  5
                               --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =     11.00   INCHES
          POROSITY                     =      0.4490 VOL/VOL
          FIELD CAPACITY               =      0.4020 VOL/VOL
          WILTING POINT                =      0.2940 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.4020 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.160000002000E-05 CM/SEC



                               LAYER  6
                               --------

                    TYPE 2 - LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =      0.20   INCHES
          POROSITY                     =      0.8500 VOL/VOL
          FIELD CAPACITY               =      0.0100 VOL/VOL
          WILTING POINT                =      0.0050 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.0116 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =   3.70000005000      CM/SEC
          SLOPE                        =      0.40   PERCENT
          DRAINAGE LENGTH              =    300.0    FEET



                               LAYER  7
                               --------

                    TYPE 4 - FLEXIBLE MEMBRANE LINER
                      MATERIAL TEXTURE NUMBER  35
          THICKNESS                    =      0.08   INCHES
          POROSITY                     =      0.0000 VOL/VOL
          FIELD CAPACITY               =      0.0000 VOL/VOL
          WILTING POINT                =      0.0000 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
          FML PINHOLE DENSITY          =      0.00   HOLES/ACRE
          FML INSTALLATION DEFECTS     =      0.00   HOLES/ACRE
          FML PLACEMENT QUALITY        =  1 - PERFECT



                               LAYER  8
                               --------

                    TYPE 2 - LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =      0.20   INCHES
          POROSITY                     =      0.8500 VOL/VOL
          FIELD CAPACITY               =      0.0100 VOL/VOL
          WILTING POINT                =      0.0050 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.0100 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =   3.70000005000      CM/SEC
          SLOPE                        =      0.40   PERCENT
          DRAINAGE LENGTH              =    300.0    FEET



                               LAYER  9
                               --------

                    TYPE 4 - FLEXIBLE MEMBRANE LINER
                      MATERIAL TEXTURE NUMBER  35
          THICKNESS                    =      0.08   INCHES
          POROSITY                     =      0.0000 VOL/VOL
          FIELD CAPACITY               =      0.0000 VOL/VOL
          WILTING POINT                =      0.0000 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
          FML PINHOLE DENSITY          =      0.00   HOLES/ACRE
          FML INSTALLATION DEFECTS     =      0.00   HOLES/ACRE
          FML PLACEMENT QUALITY        =  1 - PERFECT



                               LAYER 10
                               --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  17
          THICKNESS                    =      0.20   INCHES
          POROSITY                     =      0.7500 VOL/VOL
          FIELD CAPACITY               =      0.7470 VOL/VOL
          WILTING POINT                =      0.4000 VOL/VOL
```

```
          INITIAL SOIL WATER CONTENT  =      0.6478 VOL/VOL
          EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC



                  GENERAL DESIGN AND EVAPORATIVE ZONE DATA
                  ---------------------------------------

        NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
                 SOIL DATA BASE USING SOIL TEXTURE # 4 WITH BARE
                 GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
                 A SLOPE LENGTH OF  800. FEET.

      SCS RUNOFF CURVE NUMBER             =     80.10
      FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
      AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
      EVAPORATIVE ZONE DEPTH              =     10.0    INCHES
      INITIAL WATER IN EVAPORATIVE ZONE   =      4.310  INCHES
      UPPER LIMIT OF EVAPORATIVE STORAGE  =      4.370  INCHES
      LOWER LIMIT OF EVAPORATIVE STORAGE  =      0.470  INCHES
      INITIAL SNOW WATER                  =      0.000  INCHES
      INITIAL WATER IN LAYER MATERIALS    =     38.659  INCHES
      TOTAL INITIAL WATER                 =     38.659  INCHES
      TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR



                  EVAPOTRANSPIRATION AND WEATHER DATA
                  -----------------------------------

        NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                 GALVESTON             TEXAS

            STATION LATITUDE                      =  29.18 DEGREES
            MAXIMUM LEAF AREA INDEX               =   0.00
            START OF GROWING SEASON (JULIAN DATE) =      0
            END OF GROWING SEASON (JULIAN DATE)   =    367
            EVAPORATIVE ZONE DEPTH                =  10.0  INCHES
            AVERAGE ANNUAL WIND SPEED             =  11.00 MPH
            AVERAGE 1ST QUARTER RELATIVE HUMIDITY =  80.00 %
            AVERAGE 2ND QUARTER RELATIVE HUMIDITY =  79.00 %
            AVERAGE 3RD QUARTER RELATIVE HUMIDITY =  76.00 %
            AVERAGE 4TH QUARTER RELATIVE HUMIDITY =  77.00 %


        NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
                 COEFFICIENTS FOR    GALVESTON           TEXAS

                 NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

     JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
     -------     -------     -------     -------     -------     -------
       2.96        2.34        2.10        2.62        3.30        3.48
       3.77        4.40        5.82        2.60        3.23        3.62


        NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                 COEFFICIENTS FOR    GALVESTON           TEXAS

            NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

     JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
     -------     -------     -------     -------     -------     -------
      53.60       55.60       61.40       69.10       75.70       81.20
      83.20       83.20       80.00       72.70       63.00       56.80


        NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                 COEFFICIENTS FOR    GALVESTON           TEXAS
                   AND STATION LATITUDE  =  29.18 DEGREES



********************************************************************************

        AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH   30
--------------------------------------------------------------------------------

                        JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                        -------  -------  -------  -------  -------  -------
  PRECIPITATION
  -------------
    TOTALS                2.85     2.10     1.99     2.39     4.18     3.87
                          3.86     3.62     5.50     2.38     3.02     3.48

    STD. DEVIATIONS       1.36     1.49     1.17     1.76     2.73     2.48
                          1.98     1.77     2.73     1.37     1.96     1.82

  RUNOFF
  ------
    TOTALS                0.039    0.009    0.011    0.060    0.189    0.266
                          0.111    0.063    0.336    0.044    0.076    0.078

    STD. DEVIATIONS       0.082    0.037    0.045    0.112    0.343    0.991
                          0.163    0.137    0.428    0.120    0.145    0.165

  EVAPOTRANSPIRATION
  ------------------
    TOTALS                1.783    1.642    1.672    1.570    2.352    2.257
                          2.496    2.522    2.556    1.719    1.622    1.763

    STD. DEVIATIONS       0.526    0.681    0.783    0.879    1.178    1.111
                          1.044    0.977    0.812    0.822    0.652    0.522

  LATERAL DRAINAGE COLLECTED FROM LAYER  3
  -----------------------------------------
    TOTALS                0.0010   0.0008   0.0002   0.0001   0.0001   0.0008
                          0.0011   0.0009   0.0008   0.0023   0.0011   0.0011

    STD. DEVIATIONS       0.0015   0.0015   0.0005   0.0000   0.0003   0.0021
                          0.0021   0.0016   0.0022   0.0035   0.0017   0.0018

  PERCOLATION/LEAKAGE THROUGH LAYER  4
  -------------------------------------
    TOTALS                1.2994   1.1349   0.9958   0.8421   0.7505   0.9864
                          1.2260   1.2291   1.1248   1.6770   1.3487   1.3041

    STD. DEVIATIONS       0.6410   0.6266   0.4652   0.2001   0.2826   0.6543
                          0.7614   0.6637   0.6439   0.8743   0.6185   0.6732

  LATERAL DRAINAGE COLLECTED FROM LAYER  6
  -----------------------------------------
    TOTALS                1.1768   1.1697   1.2052   1.0728   0.9861   0.9053
                          1.0960   1.1662   1.1229   1.3133   1.3395   1.3180

    STD. DEVIATIONS       0.4629   0.4476   0.5478   0.4103   0.4646   0.3928
                          0.5119   0.4833   0.4414   0.3961   0.4040   0.4201

  PERCOLATION/LEAKAGE THROUGH LAYER  7
  -------------------------------------
    TOTALS                0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS       0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  LATERAL DRAINAGE COLLECTED FROM LAYER  8
  -----------------------------------------
    TOTALS                0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS       0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  PERCOLATION/LEAKAGE THROUGH LAYER  9
  -------------------------------------
    TOTALS                0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS       0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  PERCOLATION/LEAKAGE THROUGH LAYER 10
  ------------------------------------
    TOTALS                0.0001   0.0001   0.0001   0.0001   0.0001   0.0001
                          0.0001   0.0001   0.0001   0.0001   0.0001   0.0001

    STD. DEVIATIONS       0.0002   0.0002   0.0002   0.0001   0.0001   0.0001
                          0.0001   0.0001   0.0001   0.0001   0.0001   0.0001


--------------------------------------------------------------------------------
            AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
--------------------------------------------------------------------------------


  DAILY AVERAGE HEAD ON TOP OF LAYER  4
  -------------------------------------
    AVERAGES              0.1116   0.0891   0.0268   0.0085   0.0129   0.0854
                          0.1152   0.0980   0.0927   0.2483   0.1226   0.1169

    STD. DEVIATIONS       0.1603   0.1772   0.0523   0.0020   0.0303   0.2356
                          0.2213   0.1694   0.2438   0.3704   0.1896   0.1926

  DAILY AVERAGE HEAD ON TOP OF LAYER  7
  -------------------------------------
    AVERAGES              0.1357   0.1479   0.1390   0.1279   0.1137   0.1079
                          0.1264   0.1345   0.1338   0.1515   0.1597   0.1520

    STD. DEVIATIONS       0.0534   0.0562   0.0632   0.0489   0.0536   0.0468
                          0.0590   0.0557   0.0526   0.0457   0.0482   0.0485

  DAILY AVERAGE HEAD ON TOP OF LAYER  9
  -------------------------------------
    AVERAGES              0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS       0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                          0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

********************************************************************************
```

```
******************************************************************************

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH   30
------------------------------------------------------------------------------
                                  INCHES            CU. FEET       PERCENT
                             ---------------   -------------   ---------
 PRECIPITATION                39.24    (   6.898)     142436.4     100.00

 RUNOFF                        1.282   (  1.1280)       4655.29      3.268

 EVAPOTRANSPIRATION           23.953   (  3.4467)      86949.71     61.045

 LATERAL DRAINAGE COLLECTED    0.01034 (  0.00839)        37.525    0.02634
   FROM LAYER  3

 PERCOLATION/LEAKAGE THROUGH  13.91876 (  2.83083)     50525.094    35.47205
   LAYER  4

 AVERAGE HEAD ON TOP           0.094 (    0.075)
   OF LAYER  4

 LATERAL DRAINAGE COLLECTED   13.87191 (  2.78595)     50355.031   35.35265
   FROM LAYER  6

 PERCOLATION/LEAKAGE THROUGH   0.00000 (  0.00000)         0.016    0.00001
   LAYER  7

 AVERAGE HEAD ON TOP           0.136 (    0.027)
   OF LAYER  7

 LATERAL DRAINAGE COLLECTED    0.00000 (  0.00000)         0.007    0.00000
   FROM LAYER  8

 PERCOLATION/LEAKAGE THROUGH   0.00000 (  0.00000)         0.009    0.00001
   LAYER  9

 AVERAGE HEAD ON TOP           0.000 (    0.000)
   OF LAYER  9

 PERCOLATION/LEAKAGE THROUGH   0.00100 (  0.00156)         3.629    0.00255
   LAYER 10

 CHANGE IN WATER STORAGE       0.120   (  3.6294)        435.21     0.306
******************************************************************************


******************************************************************************

              PEAK DAILY VALUES FOR YEARS    1 THROUGH   30
   ------------------------------------------------------------------
                                            (INCHES)      (CU. FT.)
                                           ----------   ------------
      PRECIPITATION                         10.30         37389.000

      RUNOFF                                 5.440        19748.0527

      DRAINAGE COLLECTED FROM LAYER  3       0.00072          2.60298

      PERCOLATION/LEAKAGE THROUGH LAYER  4   0.183500       666.10333

      AVERAGE HEAD ON TOP OF LAYER  4        2.372

      MAXIMUM HEAD ON TOP OF LAYER  4        4.426

      LOCATION OF MAXIMUM HEAD IN LAYER  3
           (DISTANCE FROM DRAIN)             20.1 FEET

      DRAINAGE COLLECTED FROM LAYER  6       0.05442        197.56023

      PERCOLATION/LEAKAGE THROUGH LAYER  7   0.000000         0.00006

      AVERAGE HEAD ON TOP OF LAYER  7        0.195

      MAXIMUM HEAD ON TOP OF LAYER  7        1.192

      LOCATION OF MAXIMUM HEAD IN LAYER  6
           (DISTANCE FROM DRAIN)             0.0 FEET

      DRAINAGE COLLECTED FROM LAYER  8       0.00000          0.00004

      PERCOLATION/LEAKAGE THROUGH LAYER  9   0.000000         0.00002

      AVERAGE HEAD ON TOP OF LAYER  9        0.000

      MAXIMUM HEAD ON TOP OF LAYER  9        0.001

      LOCATION OF MAXIMUM HEAD IN LAYER  8
           (DISTANCE FROM DRAIN)             0.0 FEET

      PERCOLATION/LEAKAGE THROUGH LAYER 10   0.000037         0.13600

      SNOW WATER                             1.71          6208.4434


      MAXIMUM VEG. SOIL WATER (VOL/VOL)                0.4310

      MINIMUM VEG. SOIL WATER (VOL/VOL)                0.0470
```

```
      ***  Maximum heads are computed using McEnroe's equations.  ***

           Reference:  Maximum Saturated Depth over Landfill Liner
                       by Bruce M. McEnroe, University of Kansas
                       ASCE Journal of Environmental Engineering
                       Vol. 119, No. 2, March 1993, pp. 262-270.

******************************************************************************


******************************************************************************

                  FINAL WATER STORAGE AT END OF YEAR   30
     ---------------------------------------------------------------
                     LAYER        (INCHES)       (VOL/VOL)
                     -----        --------       ---------
                       1           2.0193         0.1683

                       2          32.2254         0.2066

                       3           1.6307         0.1359

                       4           0.4490         0.4490

                       5           5.6641         0.5149

                       6           0.1655         0.8273

                       7           0.0000         0.0000

                       8           0.0020         0.0100

                       9           0.0000         0.0000

                      10           0.0996         0.4982

                   SNOW WATER      0.000

******************************************************************************
******************************************************************************
```

Case FNC: Final Waste Condition – No Final Cover

```
**************************************************************************
**************************************************************************
**                                                                      **
**                                                                      **
**             HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE            **
**               HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)             **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                **
**                   USAE WATERWAYS EXPERIMENT STATION                  **
**           FOR USEPA RISK REDUCTION ENGINEERING LABORATORY            **
**                                                                      **
**                                                                      **
**************************************************************************
**************************************************************************



PRECIPITATION DATA FILE:    \RAIN25.D4
TEMPERATURE DATA FILE:      \TEMP.D7
SOLAR RADIATION DATA FILE:  \SOLAR.D13
EVAPOTRANSPIRATION DATA:    \ET_BARE.D11
SOIL AND DESIGN DATA FILE:  \FNC.D10
OUTPUT DATA FILE:           \FNC_OUT.OUT


TIME:  15:31     DATE:   8/29/2014


**************************************************************************

     TITLE:  Malone Superfund Site - Final No Cover

**************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                              LAYER  1
                              --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =     12.00   INCHES
          POROSITY                     =      0.4370 VOL/VOL
          FIELD CAPACITY               =      0.1050 VOL/VOL
          WILTING POINT                =      0.0470 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.4310 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.400000019000E-02 CM/SEC



                              LAYER  2
                              --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =    252.00   INCHES
          POROSITY                     =      0.4370 VOL/VOL
          FIELD CAPACITY               =      0.1050 VOL/VOL
          WILTING POINT                =      0.0470 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.1480 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.400000019000E-02 CM/SEC



                              LAYER  3
                              --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =     12.00   INCHES
          POROSITY                     =      0.4370 VOL/VOL
          FIELD CAPACITY               =      0.1050 VOL/VOL
          WILTING POINT                =      0.0470 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.1050 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.400000019000E-02 CM/SEC
          SLOPE                        =      0.40   PERCENT
          DRAINAGE LENGTH              =    300.0    FEET



                              LAYER  4
                              --------

                TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =      1.00   INCHES
          POROSITY                     =      0.4490 VOL/VOL
          FIELD CAPACITY               =      0.4020 VOL/VOL
          WILTING POINT                =      0.2940 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.4490 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.160000002000E-05 CM/SEC



                              LAYER  5
                              --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =     11.00   INCHES
          POROSITY                     =      0.4490 VOL/VOL
          FIELD CAPACITY               =      0.4020 VOL/VOL
          WILTING POINT                =      0.2940 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.4020 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.160000002000E-05 CM/SEC



                              LAYER  6
                              --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =      0.20   INCHES
          POROSITY                     =      0.8500 VOL/VOL
          FIELD CAPACITY               =      0.0100 VOL/VOL
          WILTING POINT                =      0.0050 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.0122 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =   3.70000005000     CM/SEC
          SLOPE                        =      0.40   PERCENT
          DRAINAGE LENGTH              =    300.0    FEET



                              LAYER  7
                              --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER  35
          THICKNESS                    =      0.08   INCHES
          POROSITY                     =      0.0000 VOL/VOL
          FIELD CAPACITY               =      0.0000 VOL/VOL
          WILTING POINT                =      0.0000 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
          FML PINHOLE DENSITY          =      0.00   HOLES/ACRE
          FML INSTALLATION DEFECTS     =      0.00   HOLES/ACRE
          FML PLACEMENT QUALITY        =  1 - PERFECT



                              LAYER  8
                              --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =      0.20   INCHES
          POROSITY                     =      0.8500 VOL/VOL
          FIELD CAPACITY               =      0.0100 VOL/VOL
          WILTING POINT                =      0.0050 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.0100 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =   3.70000005000     CM/SEC
          SLOPE                        =      0.40   PERCENT
          DRAINAGE LENGTH              =    300.0    FEET



                              LAYER  9
                              --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER  35
          THICKNESS                    =      0.08   INCHES
          POROSITY                     =      0.0000 VOL/VOL
          FIELD CAPACITY               =      0.0000 VOL/VOL
          WILTING POINT                =      0.0000 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
          FML PINHOLE DENSITY          =      0.00   HOLES/ACRE
          FML INSTALLATION DEFECTS     =      0.00   HOLES/ACRE
          FML PLACEMENT QUALITY        =  1 - PERFECT



                              LAYER 10
                              --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER  17
          THICKNESS                    =      0.20   INCHES
          POROSITY                     =      0.7500 VOL/VOL
          FIELD CAPACITY               =      0.7470 VOL/VOL
```

```
  WILTING POINT               =      0.4000 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.6465 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC



            GENERAL DESIGN AND EVAPORATIVE ZONE DATA
            ---------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 4 WITH BARE
          GROUND CONDITIONS, A SURFACE SLOPE OF  3.% AND
          A SLOPE LENGTH OF  400. FEET.

 SCS RUNOFF CURVE NUMBER             =     81.00
 FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
 AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
 EVAPORATIVE ZONE DEPTH              =     10.0    INCHES
 INITIAL WATER IN EVAPORATIVE ZONE   =      4.310  INCHES
 UPPER LIMIT OF EVAPORATIVE STORAGE  =      4.370  INCHES
 LOWER LIMIT OF EVAPORATIVE STORAGE  =      0.470  INCHES
 INITIAL SNOW WATER                  =      0.000  INCHES
 INITIAL WATER IN LAYER MATERIALS    =     48.733  INCHES
 TOTAL INITIAL WATER                 =     48.733  INCHES
 TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR



            EVAPOTRANSPIRATION AND WEATHER DATA
            ----------------------------------

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          GALVESTON            TEXAS

     STATION LATITUDE                      =  29.18 DEGREES
     MAXIMUM LEAF AREA INDEX               =   0.00
     START OF GROWING SEASON (JULIAN DATE) =      0
     END OF GROWING SEASON (JULIAN DATE)   =    367
     EVAPORATIVE ZONE DEPTH                =  10.0  INCHES
     AVERAGE ANNUAL WIND SPEED             =  11.00 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY =  80.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY =  79.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY =  76.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY =  77.00 %


 NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    GALVESTON           TEXAS

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

  JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
  -------     -------     -------     -------     -------     -------
    2.96        2.34        2.10        2.62        3.30        3.48
    3.77        4.40        5.82        2.60        3.23        3.62


 NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    GALVESTON           TEXAS

      NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

  JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
  -------     -------     -------     -------     -------     -------
   53.60       55.60       61.40       69.10       75.70       81.20
   83.20       83.20       80.00       72.70       63.00       56.80


 NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    GALVESTON           TEXAS
            AND STATION LATITUDE  =  29.18 DEGREES



********************************************************************************

      AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH   30
--------------------------------------------------------------------------------

                      JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                      -------  -------  -------  -------  -------  -------
 PRECIPITATION
 -------------
   TOTALS               2.85     2.10     1.99     2.39     4.18     3.87
                        3.86     3.62     5.50     2.38     3.02     3.48

   STD. DEVIATIONS      1.36     1.49     1.17     1.76     2.73     2.48
                        1.98     1.77     2.73     1.37     1.96     1.82

 RUNOFF
 ------
   TOTALS               0.047    0.010    0.014    0.070    0.214    0.289
                        0.130    0.076    0.376    0.052    0.090    0.090

   STD. DEVIATIONS      0.095    0.043    0.052    0.128    0.373    1.025
                        0.180    0.157    0.463    0.133    0.163    0.185

 EVAPOTRANSPIRATION
 ------------------
   TOTALS               1.781    1.641    1.674    1.570    2.356    2.254
                        2.495    2.523    2.557    1.719    1.621    1.766

   STD. DEVIATIONS      0.528    0.681    0.787    0.880    1.179    1.112
                        1.047    0.975    0.816    0.823    0.651    0.523

 LATERAL DRAINAGE COLLECTED FROM LAYER  3
 ----------------------------------------
   TOTALS               0.0008   0.0007   0.0003   0.0001   0.0001   0.0003
                        0.0005   0.0007   0.0005   0.0013   0.0009   0.0008

   STD. DEVIATIONS      0.0013   0.0012   0.0008   0.0001   0.0000   0.0012
                        0.0010   0.0012   0.0012   0.0025   0.0017   0.0011

 PERCOLATION/LEAKAGE THROUGH LAYER  4
 --------------------------------------
   TOTALS               1.2406   1.1233   1.1188   0.9768   0.8013   0.8389
                        1.0939   1.1554   1.0602   1.4085   1.3385   1.2994

   STD. DEVIATIONS      0.6106   0.6086   0.5262   0.2811   0.2863   0.4516
                        0.5355   0.6102   0.4992   0.7064   0.5895   0.5269

 LATERAL DRAINAGE COLLECTED FROM LAYER  6
 ----------------------------------------
   TOTALS               1.1496   1.0906   1.1761   1.1207   1.0290   0.8725
                        1.0374   1.1015   1.1047   1.1904   1.2793   1.2753

   STD. DEVIATIONS      0.4938   0.4512   0.5461   0.4120   0.4228   0.4135
                        0.4426   0.4712   0.4374   0.4187   0.3711   0.3872

 PERCOLATION/LEAKAGE THROUGH LAYER  7
 --------------------------------------
   TOTALS               0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

   STD. DEVIATIONS      0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

 LATERAL DRAINAGE COLLECTED FROM LAYER  8
 ----------------------------------------
   TOTALS               0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

   STD. DEVIATIONS      0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

 PERCOLATION/LEAKAGE THROUGH LAYER  9
 --------------------------------------
   TOTALS               0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

   STD. DEVIATIONS      0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

 PERCOLATION/LEAKAGE THROUGH LAYER 10
 --------------------------------------
   TOTALS               0.0001   0.0001   0.0001   0.0001   0.0001   0.0001
                        0.0001   0.0001   0.0001   0.0001   0.0001   0.0001

   STD. DEVIATIONS      0.0002   0.0002   0.0002   0.0001   0.0001   0.0001
                        0.0001   0.0001   0.0001   0.0001   0.0001   0.0001

--------------------------------------------------------------------------------
          AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
--------------------------------------------------------------------------------


 DAILY AVERAGE HEAD ON TOP OF LAYER  4
 --------------------------------------
   AVERAGES             0.0858   0.0816   0.0374   0.0130   0.0091   0.0374
                        0.0544   0.0740   0.0571   0.1372   0.1005   0.0812

   STD. DEVIATIONS      0.1355   0.1428   0.0824   0.0162   0.0040   0.1347
                        0.1024   0.1329   0.1284   0.2654   0.1849   0.1169

 DAILY AVERAGE HEAD ON TOP OF LAYER  7
 --------------------------------------
   AVERAGES             0.1326   0.1378   0.1357   0.1336   0.1187   0.1040
                        0.1197   0.1271   0.1317   0.1373   0.1525   0.1471

   STD. DEVIATIONS      0.0570   0.0566   0.0630   0.0491   0.0488   0.0493
                        0.0511   0.0544   0.0521   0.0483   0.0442   0.0447

 DAILY AVERAGE HEAD ON TOP OF LAYER  9
 --------------------------------------
   AVERAGES             0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

   STD. DEVIATIONS      0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

********************************************************************************
```

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	39.24 (6.898)	142436.4	100.00
RUNOFF	1.458 (1.1940)	5291.36	3.715
EVAPOTRANSPIRATION	23.957 (3.4634)	86963.25	61.054
LATERAL DRAINAGE COLLECTED FROM LAYER 3	0.00701 (0.00653)	25.449	0.01787
PERCOLATION/LEAKAGE THROUGH LAYER 4	13.45572 (2.98955)	48844.262	34.29199
AVERAGE HEAD ON TOP OF LAYER 4	0.064 (0.059)		
LATERAL DRAINAGE COLLECTED FROM LAYER 6	13.42711 (3.08289)	48740.410	34.21908
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00000 (0.00000)	0.016	0.00001
AVERAGE HEAD ON TOP OF LAYER 7	0.131 (0.030)		
LATERAL DRAINAGE COLLECTED FROM LAYER 8	0.00000 (0.00000)	0.007	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.00000 (0.00000)	0.009	0.00001
AVERAGE HEAD ON TOP OF LAYER 9	0.000 (0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.00099 (0.00153)	3.598	0.00253
CHANGE IN WATER STORAGE	0.389 (3.9977)	1412.30	0.992

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	10.30	37389.000
RUNOFF	5.630	20435.8320
DRAINAGE COLLECTED FROM LAYER 3	0.00047	1.68977
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.138216	501.72290
AVERAGE HEAD ON TOP OF LAYER 4	1.540	
MAXIMUM HEAD ON TOP OF LAYER 4	3.491	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	0.0 FEET	
DRAINAGE COLLECTED FROM LAYER 6	0.05442	197.56023
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000000	0.00006
AVERAGE HEAD ON TOP OF LAYER 7	0.195	
MAXIMUM HEAD ON TOP OF LAYER 7	1.192	
LOCATION OF MAXIMUM HEAD IN LAYER 6 (DISTANCE FROM DRAIN)	0.0 FEET	
DRAINAGE COLLECTED FROM LAYER 8	0.00000	0.00004
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000000	0.00002
AVERAGE HEAD ON TOP OF LAYER 9	0.000	
MAXIMUM HEAD ON TOP OF LAYER 9	0.001	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.000036	0.13190
SNOW WATER	1.71	6208.4434

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4310

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0470

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	2.0193	0.1683
2	51.1283	0.2029
3	1.4239	0.1187
4	0.4490	0.4490
5	5.1175	0.4652
6	0.1650	0.8251
7	0.0000	0.0000
8	0.0020	0.0100
9	0.0000	0.0000
10	0.0996	0.4982
SNOW WATER	0.000	

Written by: **A. Brown** Date: **7/28/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT** Project: **Malone Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Case FC: Final Cover Condition

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**************************************************************************
**************************************************************************
**                                                                      **
**                                                                      **
**            HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE             **
**              HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)              **
**                DEVELOPED BY ENVIRONMENTAL LABORATORY                 **
**                  USAE WATERWAYS EXPERIMENT STATION                   **
**           FOR USEPA RISK REDUCTION ENGINEERING LABORATORY            **
**                                                                      **
**                                                                      **
**************************************************************************
**************************************************************************



PRECIPITATION DATA FILE:    \RAIN25.D4
TEMPERATURE DATA FILE:      \TEMP.D7
SOLAR RADIATION DATA FILE:  \SOLAR.D13
EVAPOTRANSPIRATION DATA:    \ET_VEG.D11
SOIL AND DESIGN DATA FILE:  \FC.D10
OUTPUT DATA FILE:           \FC_OUT.OUT


TIME:   8:55     DATE:   8/29/2014



**************************************************************************

     TITLE:  Malone Superfund Site - Final Cover Case

**************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
               COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                LAYER  1
                                --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER  11
          THICKNESS                    =      6.00   INCHES
          POROSITY                     =      0.4640 VOL/VOL
          FIELD CAPACITY               =      0.3100 VOL/VOL
          WILTING POINT                =      0.1870 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.1933 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.639999998000E-04 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.63
                FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.



                                LAYER  2
                                --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =     12.00   INCHES
          POROSITY                     =      0.4490 VOL/VOL
          FIELD CAPACITY               =      0.4020 VOL/VOL
          WILTING POINT                =      0.2940 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3840 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.190000003000E-05 CM/SEC



                                LAYER  3
                                --------

                  TYPE 2 - LATERAL DRAINAGE LAYER
                    MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =      0.20   INCHES
          POROSITY                     =      0.8500 VOL/VOL
          FIELD CAPACITY               =      0.0100 VOL/VOL
          WILTING POINT                =      0.0050 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.1365 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.639999986000     CM/SEC
          SLOPE                        =      3.00   PERCENT
          DRAINAGE LENGTH              =    400.0    FEET



                                LAYER  4
                                --------

                  TYPE 4 - FLEXIBLE MEMBRANE LINER
                    MATERIAL TEXTURE NUMBER  36
          THICKNESS                    =      0.04   INCHES
          POROSITY                     =      0.0000 VOL/VOL
          FIELD CAPACITY               =      0.0000 VOL/VOL
          WILTING POINT                =      0.0000 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.399999993000E-12 CM/SEC
          FML PINHOLE DENSITY          =      2.00   HOLES/ACRE
          FML INSTALLATION DEFECTS     =      2.00   HOLES/ACRE
          FML PLACEMENT QUALITY        =  4 - POOR



                                LAYER  5
                                --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER  17
          THICKNESS                    =      0.20   INCHES
          POROSITY                     =      0.7500 VOL/VOL
          FIELD CAPACITY               =      0.7470 VOL/VOL
          WILTING POINT                =      0.4000 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.6270 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC



                                LAYER  6
                                --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =      0.20   INCHES
          POROSITY                     =      0.8500 VOL/VOL
          FIELD CAPACITY               =      0.0100 VOL/VOL
          WILTING POINT                =      0.0050 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.0100 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.730000019000     CM/SEC



                                LAYER  7
                                --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =    264.00   INCHES
          POROSITY                     =      0.4370 VOL/VOL
          FIELD CAPACITY               =      0.1050 VOL/VOL
          WILTING POINT                =      0.0470 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.1050 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.400000019000E-02 CM/SEC



                                LAYER  8
                                --------

                  TYPE 2 - LATERAL DRAINAGE LAYER
                    MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =     12.00   INCHES
          POROSITY                     =      0.4370 VOL/VOL
          FIELD CAPACITY               =      0.1050 VOL/VOL
          WILTING POINT                =      0.0470 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.1050 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.400000019000E-02 CM/SEC
          SLOPE                        =      0.40   PERCENT
          DRAINAGE LENGTH              =    300.0    FEET



                                LAYER  9
                                --------

                  TYPE 3 - BARRIER SOIL LINER
                    MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =      1.00   INCHES
          POROSITY                     =      0.4490 VOL/VOL
          FIELD CAPACITY               =      0.4020 VOL/VOL
          WILTING POINT                =      0.2940 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.4490 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.160000002000E-05 CM/SEC



                                LAYER 10
                                --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =     11.00   INCHES
          POROSITY                     =      0.4490 VOL/VOL
          FIELD CAPACITY               =      0.4020 VOL/VOL
          WILTING POINT                =      0.2940 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.4020 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.160000002000E-05 CM/SEC
```

```
                        LAYER 11
                        --------

             TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.20   INCHES
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0642 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC
SLOPE                        =      0.40   PERCENT
DRAINAGE LENGTH              =    300.0    FEET



                        LAYER 12
                        --------

             TYPE 4 - FLEXIBLE MEMBRANE LINER
               MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.08   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      0.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  1 - PERFECT



                        LAYER 13
                        --------

             TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.20   INCHES
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999978000E-02 CM/SEC
SLOPE                        =      0.40   PERCENT
DRAINAGE LENGTH              =    300.0    FEET



                        LAYER 14
                        --------

             TYPE 4 - FLEXIBLE MEMBRANE LINER
               MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.08   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      0.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  1 - PERFECT



                        LAYER 15
                        --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER  17
THICKNESS                    =      0.20   INCHES
POROSITY                     =      0.7500 VOL/VOL
FIELD CAPACITY               =      0.7470 VOL/VOL
WILTING POINT                =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.6259 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC



          GENERAL DESIGN AND EVAPORATIVE ZONE DATA
          ---------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #11 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  400. FEET.

SCS RUNOFF CURVE NUMBER             =     81.70
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =     18.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      5.768  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      8.172  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      4.650  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =     39.925  INCHES
TOTAL INITIAL WATER                 =     39.925  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR



               EVAPOTRANSPIRATION AND WEATHER DATA
               ----------------------------------

          NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                   GALVESTON            TEXAS

              STATION LATITUDE                        =  29.18 DEGREES
              MAXIMUM LEAF AREA INDEX                 =   3.50
              START OF GROWING SEASON (JULIAN DATE)   =     0
              END OF GROWING SEASON (JULIAN DATE)     =   367
              EVAPORATIVE ZONE DEPTH                  =  18.0  INCHES
              AVERAGE ANNUAL WIND SPEED               =  11.00 MPH
              AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  80.00 %
              AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  79.00 %
              AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  76.00 %
              AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  77.00 %


          NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
                   COEFFICIENTS FOR    GALVESTON            TEXAS

                   NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

    JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
    -------     -------     -------     -------     -------     -------
      2.96        2.34        2.10        2.62        3.30        3.48
      3.77        4.40        5.82        2.60        3.23        3.62


          NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                   COEFFICIENTS FOR    GALVESTON            TEXAS

               NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

    JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
    -------     -------     -------     -------     -------     -------
     53.60       55.60       61.40       69.10       75.70       81.20
     83.20       83.20       80.00       72.70       63.00       56.80


          NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                   COEFFICIENTS FOR    GALVESTON            TEXAS
                     AND STATION LATITUDE  =  29.18 DEGREES



********************************************************************************

          AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH   30
--------------------------------------------------------------------------------

                        JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                        -------  -------  -------  -------  -------  -------
  PRECIPITATION
  -------------
    TOTALS                2.85     2.10     1.99     2.39     4.18     3.87
                          3.86     3.62     5.50     2.38     3.02     3.48

    STD. DEVIATIONS       1.36     1.49     1.17     1.76     2.73     2.48
                          1.98     1.77     2.73     1.37     1.96     1.82

  RUNOFF
  ------
    TOTALS                0.626    0.219    0.068    0.278    0.786    0.708
                          0.492    0.347    1.611    0.223    0.678    0.865

    STD. DEVIATIONS       0.937    0.452    0.224    0.536    1.176    1.621
                          0.639    0.935    1.569    0.477    0.977    1.100

  EVAPOTRANSPIRATION
  ------------------
    TOTALS                1.431    2.632    2.685    2.004    3.273    3.348
                          3.282    3.287    3.377    2.357    1.597    1.217

    STD. DEVIATIONS       0.355    0.349    1.155    1.002    1.619    1.626
                          1.258    1.303    1.079    1.255    0.557    0.299

  LATERAL DRAINAGE COLLECTED FROM LAYER  3
  ----------------------------------------
    TOTALS                0.7795   0.4361   0.1097   0.0080   0.0012   0.0010
                          0.0006   0.0004   0.0005   0.0014   0.0236   0.4110

    STD. DEVIATIONS       0.5499   0.3771   0.1725   0.0273   0.0028   0.0024
                          0.0016   0.0009   0.0013   0.0033   0.1271   0.4885
```

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
STD. DEVIATIONS	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002

LATERAL DRAINAGE COLLECTED FROM LAYER 8

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.0001	0.0003	0.0002	0.0002	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0002	0.0007	0.0008	0.0007	0.0002	0.0001
	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 11

TOTALS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
STD. DEVIATIONS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

PERCOLATION/LEAKAGE THROUGH LAYER 12

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 13

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 14

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 15

TOTALS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
STD. DEVIATIONS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	1.8379	0.2001	0.0130	0.0010	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0002	0.0684	0.6936
STD. DEVIATIONS	2.1222	0.4719	0.0205	0.0034	0.0003	0.0003
	0.0002	0.0001	0.0002	0.0004	0.3746	1.6462

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

DAILY AVERAGE HEAD ON TOP OF LAYER 12

AVERAGES	0.0041	0.0043	0.0045	0.0045	0.0045	0.0044
	0.0043	0.0042	0.0041	0.0040	0.0039	0.0038
STD. DEVIATIONS	0.0053	0.0054	0.0056	0.0059	0.0062	0.0061
	0.0060	0.0058	0.0057	0.0055	0.0054	0.0052

DAILY AVERAGE HEAD ON TOP OF LAYER 14

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	39.24	(6.898)	142436.4	100.00
RUNOFF	6.901	(3.3170)	25051.45	17.588
EVAPOTRANSPIRATION	30.490	(4.4479)	110677.91	77.703
LATERAL DRAINAGE COLLECTED FROM LAYER 3	1.77297	(0.96970)	6435.889	4.51843
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00034	(0.00039)	1.225	0.00086
AVERAGE HEAD ON TOP OF LAYER 4	0.235	(0.247)		
LATERAL DRAINAGE COLLECTED FROM LAYER 8	0.00000	(0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.00084	(0.00270)	3.037	0.00213
AVERAGE HEAD ON TOP OF LAYER 9	0.000	(0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 11	0.00117	(0.00155)	4.238	0.00298
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.00000	(0.00000)	0.009	0.00001
AVERAGE HEAD ON TOP OF LAYER 12	0.004	(0.006)		
LATERAL DRAINAGE COLLECTED FROM LAYER 13	0.00000	(0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 14	0.00000	(0.00000)	0.009	0.00001
AVERAGE HEAD ON TOP OF LAYER 14	0.000	(0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 15	0.00086	(0.00112)	3.109	0.00218
CHANGE IN WATER STORAGE	0.073	(1.1606)	263.79	0.185

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	10.30	37389.000
RUNOFF	8.400	30492.9531
DRAINAGE COLLECTED FROM LAYER 3	0.05500	199.63252
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000103	0.37516
AVERAGE HEAD ON TOP OF LAYER 4	17.477	
MAXIMUM HEAD ON TOP OF LAYER 4	25.846	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	104.0 FEET	
DRAINAGE COLLECTED FROM LAYER 8	0.00000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000175	0.63367
AVERAGE HEAD ON TOP OF LAYER 9	0.000	
MAXIMUM HEAD ON TOP OF LAYER 9	0.003	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	0.0 FEET	
DRAINAGE COLLECTED FROM LAYER 11	0.00002	0.07447
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.000000	0.00002
AVERAGE HEAD ON TOP OF LAYER 12	0.027	

```
      MAXIMUM HEAD ON TOP OF LAYER 12           0.442

      LOCATION OF MAXIMUM HEAD IN LAYER 11
           (DISTANCE FROM DRAIN)                0.0 FEET

      DRAINAGE COLLECTED FROM LAYER 13          0.00000          0.00000

      PERCOLATION/LEAKAGE THROUGH LAYER 14      0.000000         0.00002

      AVERAGE HEAD ON TOP OF LAYER 14           0.000

      MAXIMUM HEAD ON TOP OF LAYER 14           0.000

      LOCATION OF MAXIMUM HEAD IN LAYER 13
           (DISTANCE FROM DRAIN)                0.0 FEET

      PERCOLATION/LEAKAGE THROUGH LAYER 15      0.000022         0.08026

      SNOW WATER                                1.71          6208.4434


      MAXIMUM VEG. SOIL WATER (VOL/VOL)                 0.4540

      MINIMUM VEG. SOIL WATER (VOL/VOL)                 0.2583


       ***  Maximum heads are computed using McEnroe's equations.  ***

            Reference:  Maximum Saturated Depth over Landfill Liner
                        by Bruce M. McEnroe, University of Kansas
                        ASCE Journal of Environmental Engineering
                        Vol. 119, No. 2, March 1993, pp. 262-270.

********************************************************************************



********************************************************************************

                  FINAL WATER STORAGE AT END OF YEAR   30
    ---------------------------------------------------------------------
                    LAYER        (INCHES)       (VOL/VOL)
                    -----        --------       ---------
                      1            2.5164         0.4194
                      2            5.3474         0.4456
                      3            0.1621         0.8104
                      4            0.0000         0.0000
                      5            0.1217         0.6086
                      6            0.0020         0.0100
                      7           27.7200         0.1050
                      8            1.2600         0.1050
                      9            0.4490         0.4490
                     10            4.4220         0.4020
                     11            0.0028         0.0142
                     12            0.0000         0.0000
                     13            0.0020         0.0100
                     14            0.0000         0.0000
                     15            0.0996         0.4978
                  SNOW WATER       0.000

********************************************************************************
********************************************************************************
```

Written by: **A. Brown** Date: **7/28/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT** Project: **Malone Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Special Case FC-S: Final Cover Condition

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**************************************************************************
**************************************************************************
**                                                                      **
**                                                                      **
**             HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE             **
**               HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)             **
**                 DEVELOPED BY ENVIRONMENTAL LABORATORY                **
**                   USAE WATERWAYS EXPERIMENT STATION                  **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY           **
**                                                                      **
**                                                                      **
**************************************************************************
**************************************************************************



PRECIPITATION DATA FILE:    \RAIN25.D4
TEMPERATURE DATA FILE:      \TEMP.D7
SOLAR RADIATION DATA FILE:  \SOLAR.D13
EVAPOTRANSPIRATION DATA:    \ET_VEG.D11
SOIL AND DESIGN DATA FILE:  \fc_s.D10
OUTPUT DATA FILE:           \FCS_OUT.OUT


TIME:   8:50     DATE:   8/29/2014



**************************************************************************

     TITLE:  Malone Superfund Site - Final Cover Drainage Layer

**************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                LAYER  1
                                --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER  11
          THICKNESS                    =      6.00   INCHES
          POROSITY                     =      0.4640 VOL/VOL
          FIELD CAPACITY               =      0.3100 VOL/VOL
          WILTING POINT                =      0.1870 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.1933 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.639999998000E-04 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.63
                FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.



                                LAYER  2
                                --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =     12.00   INCHES
          POROSITY                     =      0.4490 VOL/VOL
          FIELD CAPACITY               =      0.4020 VOL/VOL
          WILTING POINT                =      0.2940 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3840 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.190000003000E-05 CM/SEC



                                LAYER  3
                                --------

                  TYPE 2 - LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =      0.20   INCHES
          POROSITY                     =      0.8500 VOL/VOL
          FIELD CAPACITY               =      0.0100 VOL/VOL
          WILTING POINT                =      0.0050 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.1130 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.730000019000     CM/SEC
          SLOPE                        =      3.00   PERCENT
          DRAINAGE LENGTH              =    400.0    FEET



                                LAYER  4
                                --------

                  TYPE 4 - FLEXIBLE MEMBRANE LINER
                      MATERIAL TEXTURE NUMBER  36
          THICKNESS                    =      0.04   INCHES
          POROSITY                     =      0.0000 VOL/VOL
          FIELD CAPACITY               =      0.0000 VOL/VOL
          WILTING POINT                =      0.0000 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.399999993000E-12 CM/SEC
          FML PINHOLE DENSITY          =      0.00   HOLES/ACRE
          FML INSTALLATION DEFECTS     =      0.00   HOLES/ACRE
          FML PLACEMENT QUALITY        =  1 - PERFECT



                                LAYER  5
                                --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER  17
          THICKNESS                    =      0.20   INCHES
          POROSITY                     =      0.7500 VOL/VOL
          FIELD CAPACITY               =      0.7470 VOL/VOL
          WILTING POINT                =      0.4000 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.6269 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC



                                LAYER  6
                                --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =      0.20   INCHES
          POROSITY                     =      0.8500 VOL/VOL
          FIELD CAPACITY               =      0.0100 VOL/VOL
          WILTING POINT                =      0.0050 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.0100 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.730000019000     CM/SEC



                                LAYER  7
                                --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =    264.00   INCHES
          POROSITY                     =      0.4370 VOL/VOL
          FIELD CAPACITY               =      0.1050 VOL/VOL
          WILTING POINT                =      0.0470 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.1050 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.400000019000E-02 CM/SEC



                                LAYER  8
                                --------

                  TYPE 2 - LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =     12.00   INCHES
          POROSITY                     =      0.4370 VOL/VOL
          FIELD CAPACITY               =      0.1050 VOL/VOL
          WILTING POINT                =      0.0470 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.1050 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.400000019000E-02 CM/SEC
          SLOPE                        =      0.40   PERCENT
          DRAINAGE LENGTH              =    300.0    FEET



                                LAYER  9
                                --------

                  TYPE 3 - BARRIER SOIL LINER
                      MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =      1.00   INCHES
          POROSITY                     =      0.4490 VOL/VOL
          FIELD CAPACITY               =      0.4020 VOL/VOL
          WILTING POINT                =      0.2940 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.4490 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.160000002000E-05 CM/SEC



                                LAYER 10
                                --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                      MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =     11.00   INCHES
          POROSITY                     =      0.4490 VOL/VOL
          FIELD CAPACITY               =      0.4020 VOL/VOL
          WILTING POINT                =      0.2940 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.4020 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.160000002000E-05 CM/SEC
```

```
                        LAYER 11
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.20   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0639 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999978000E-02 CM/SEC
SLOPE                       =      0.40   PERCENT
DRAINAGE LENGTH             =    300.0    FEET



                        LAYER 12
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.08   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =      0.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  1 - PERFECT



                        LAYER 13
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.20   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999978000E-02 CM/SEC
SLOPE                       =      0.40   PERCENT
DRAINAGE LENGTH             =    300.0    FEET



                        LAYER 14
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.08   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =      0.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  1 - PERFECT



                        LAYER 15
                        --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  17
THICKNESS                   =      0.20   INCHES
POROSITY                    =      0.7500 VOL/VOL
FIELD CAPACITY              =      0.7470 VOL/VOL
WILTING POINT               =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.6259 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC



          GENERAL DESIGN AND EVAPORATIVE ZONE DATA
          ---------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #11 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  400. FEET.

SCS RUNOFF CURVE NUMBER             =     81.70
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =     18.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      5.768  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      8.172  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      4.650  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =     39.920  INCHES
TOTAL INITIAL WATER                 =     39.920  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR



                EVAPOTRANSPIRATION AND WEATHER DATA
                ----------------------------------

          NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
                   GALVESTON            TEXAS

              STATION LATITUDE                        =  29.18 DEGREES
              MAXIMUM LEAF AREA INDEX                 =   3.50
              START OF GROWING SEASON (JULIAN DATE)   =     0
              END OF GROWING SEASON (JULIAN DATE)     =   367
              EVAPORATIVE ZONE DEPTH                  =  18.0  INCHES
              AVERAGE ANNUAL WIND SPEED               =  11.00 MPH
              AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  80.00 %
              AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  79.00 %
              AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  76.00 %
              AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  77.00 %


          NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
                   COEFFICIENTS FOR    GALVESTON            TEXAS

                   NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

    JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
    -------     -------     -------     -------     -------     -------
      2.96        2.34        2.10        2.62        3.30        3.48
      3.77        4.40        5.82        2.60        3.23        3.62


          NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                   COEFFICIENTS FOR    GALVESTON            TEXAS

               NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

    JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
    -------     -------     -------     -------     -------     -------
     53.60       55.60       61.40       69.10       75.70       81.20
     83.20       83.20       80.00       72.70       63.00       56.80


          NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                   COEFFICIENTS FOR    GALVESTON            TEXAS
                     AND STATION LATITUDE  =  29.18 DEGREES



********************************************************************************

        AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH   30
--------------------------------------------------------------------------------

                        JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                        -------  -------  -------  -------  -------  -------
  PRECIPITATION
  -------------
    TOTALS                2.85     2.10     1.99     2.39     4.18     3.87
                          3.86     3.62     5.50     2.38     3.02     3.48

    STD. DEVIATIONS       1.36     1.49     1.17     1.76     2.73     2.48
                          1.98     1.77     2.73     1.37     1.96     1.82

  RUNOFF
  ------
    TOTALS                0.624    0.218    0.068    0.278    0.787    0.708
                          0.492    0.347    1.611    0.223    0.678    0.864

    STD. DEVIATIONS       0.931    0.451    0.224    0.536    1.176    1.621
                          0.639    0.935    1.569    0.477    0.977    1.099

  EVAPOTRANSPIRATION
  ------------------
    TOTALS                1.431    2.634    2.686    2.004    3.274    3.348
                          3.282    3.287    3.377    2.357    1.597    1.217

    STD. DEVIATIONS       0.355    0.346    1.155    1.002    1.619    1.625
                          1.258    1.303    1.079    1.255    0.558    0.299

  LATERAL DRAINAGE COLLECTED FROM LAYER  3
  ----------------------------------------
    TOTALS                0.7852   0.4214   0.1056   0.0075   0.0011   0.0006
                          0.0004   0.0003   0.0004   0.0012   0.0253   0.4243

    STD. DEVIATIONS       0.5542   0.3738   0.1696   0.0274   0.0027   0.0015
                          0.0014   0.0007   0.0013   0.0031   0.1364   0.4984
```

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 8

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.0000	0.0001	0.0001	0.0001	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0002	0.0007	0.0008	0.0007	0.0002	0.0001
	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 11

TOTALS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
STD. DEVIATIONS	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001
	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001

PERCOLATION/LEAKAGE THROUGH LAYER 12

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 13

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 14

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 15

TOTALS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
STD. DEVIATIONS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0817	0.0481	0.0110	0.0008	0.0001	0.0001
	0.0000	0.0000	0.0000	0.0001	0.0027	0.0441
STD. DEVIATIONS	0.0576	0.0425	0.0176	0.0029	0.0003	0.0002
	0.0001	0.0001	0.0001	0.0003	0.0147	0.0518

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

DAILY AVERAGE HEAD ON TOP OF LAYER 12

AVERAGES	0.0032	0.0032	0.0032	0.0033	0.0033	0.0033
	0.0032	0.0031	0.0030	0.0030	0.0029	0.0028
STD. DEVIATIONS	0.0057	0.0058	0.0060	0.0064	0.0066	0.0065
	0.0064	0.0062	0.0061	0.0059	0.0058	0.0056

DAILY AVERAGE HEAD ON TOP OF LAYER 14

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	39.24 (6.898)	142436.4	100.00
RUNOFF	6.898 (3.3162)	25039.32	17.579
EVAPOTRANSPIRATION	30.494 (4.4470)	110691.41	77.713
LATERAL DRAINAGE COLLECTED FROM LAYER 3	1.77335 (0.97531)	6437.255	4.51939
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00000 (0.00000)	0.014	0.00001
AVERAGE HEAD ON TOP OF LAYER 4	0.016 (0.009)		
LATERAL DRAINAGE COLLECTED FROM LAYER 8	0.00000 (0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.00051 (0.00275)	1.837	0.00129
AVERAGE HEAD ON TOP OF LAYER 9	0.000 (0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 11	0.00086 (0.00166)	3.131	0.00220
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.00000 (0.00000)	0.009	0.00001
AVERAGE HEAD ON TOP OF LAYER 12	0.003 (0.006)		
LATERAL DRAINAGE COLLECTED FROM LAYER 13	0.00000 (0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 14	0.00000 (0.00000)	0.009	0.00001
AVERAGE HEAD ON TOP OF LAYER 14	0.000 (0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 15	0.00086 (0.00112)	3.109	0.00218
CHANGE IN WATER STORAGE	0.072 (1.1493)	262.12	0.184

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	10.30	37389.000
RUNOFF	8.400	30493.0371
DRAINAGE COLLECTED FROM LAYER 3	0.06125	222.31958
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000000	0.00024
AVERAGE HEAD ON TOP OF LAYER 4	0.197	
MAXIMUM HEAD ON TOP OF LAYER 4	0.390	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	5.1 FEET	
DRAINAGE COLLECTED FROM LAYER 8	0.00000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000175	0.63359
AVERAGE HEAD ON TOP OF LAYER 9	0.000	
MAXIMUM HEAD ON TOP OF LAYER 9	0.003	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	0.0 FEET	
DRAINAGE COLLECTED FROM LAYER 11	0.00002	0.07458
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.000000	0.00002
AVERAGE HEAD ON TOP OF LAYER 12	0.027	

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      MAXIMUM HEAD ON TOP OF LAYER 12           0.443

      LOCATION OF MAXIMUM HEAD IN LAYER 11
           (DISTANCE FROM DRAIN)                0.0 FEET

      DRAINAGE COLLECTED FROM LAYER 13          0.00000          0.00000

      PERCOLATION/LEAKAGE THROUGH LAYER 14      0.000000         0.00002

      AVERAGE HEAD ON TOP OF LAYER 14           0.000

      MAXIMUM HEAD ON TOP OF LAYER 14           0.000

      LOCATION OF MAXIMUM HEAD IN LAYER 13
           (DISTANCE FROM DRAIN)                0.0 FEET

      PERCOLATION/LEAKAGE THROUGH LAYER 15      0.000022         0.08026

      SNOW WATER                                1.71          6208.4434


      MAXIMUM VEG. SOIL WATER (VOL/VOL)                 0.4520

      MINIMUM VEG. SOIL WATER (VOL/VOL)                 0.2583


       ***  Maximum heads are computed using McEnroe's equations.  ***

            Reference:  Maximum Saturated Depth over Landfill Liner
                        by Bruce M. McEnroe, University of Kansas
                        ASCE Journal of Environmental Engineering
                        Vol. 119, No. 2, March 1993, pp. 262-270.

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                  FINAL WATER STORAGE AT END OF YEAR   30
    ---------------------------------------------------------------------
                   LAYER        (INCHES)       (VOL/VOL)
                   -----        --------       ---------
                     1            2.5164         0.4194
                     2            5.3474         0.4456
                     3            0.1445         0.7223
                     4            0.0000         0.0000
                     5            0.1217         0.6086
                     6            0.0020         0.0100
                     7           27.7200         0.1050
                     8            1.2600         0.1050
                     9            0.4490         0.4490
                    10            4.4220         0.4020
                    11            0.0020         0.0100
                    12            0.0000         0.0000
                    13            0.0020         0.0100
                    14            0.0000         0.0000
                    15            0.0996         0.4978
                 SNOW WATER       0.000

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GEOTEXTILE FILTER DESIGN

Written by: **A. Brown** Date: **7/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT** Project: **Malone Superfund Site** Project No.: **TXL0299** Phase No.: **02**

GEOTEXTILE FILTER DESIGN

GEOSYNTEC CONSULTANTS, INC.
TEXAS ENGINEERING FIRM
REGISTRATION NO. F-1182

SEALED FOR CALCULATION PAGES
1 THROUGH 9

1. PURPOSE

The purpose of this calculation package is to present the design for minimum specified properties of the geotextile component of the geosynthetic drainage layer of the liner system for the Malone Service Company Superfund Site RCRA Subtitle C Cell. As shown on the proposed liner system details, a geocomposite drainage layer is proposed to serve as the leachate collection layer, and another geocomposite drainage layer is proposed to serve as the leak detection layer. A geocomposite drainage layer will also be included in the final cover system. The geocomposite will be composed of non-woven geotextiles bonded to the top and bottom of a geonet drainage core.

The items evaluated in this design evaluation include: (i) filtration capability and specifications for the geotextile component of the geocomposite drainage layer; and (ii) survivability specifications for the geotextiles. It is noted that the drainage layer design (hydraulic capacity) is presented in the Leachate Collection System and Leak Detection System Drainage Layer Design calculation package.

2. METHODS OF ANALYSIS

2.1 Geotextile Filtration

The filtration characteristics of the geotextile component of the geocomposite layer will be evaluated using a retention criterion, a permeability criterion, and an anti-clogging criterion,

based on methods presented in the following technical literature: Christopher and Holtz (1984), Giroud (1982), Koerner et al. (1994), USEPA (1987).

2.2 Geotextile Survivability

Survivability requirements (grab, tear, and puncture strengths) will also be considered so that the geotextile component of the geocomposite will have adequate resistance to stresses applied on the geotextile during construction (i.e., when concentrated stresses should be the highest), using the method presented in GRI-GT13 (2004).

As each criterion is evaluated and minimum specifications are derived, characteristics of geotextile products on the current market are checked to ensure the specification is reasonable and that products are available that can meet the specification. Also, this calculation package presents minimum required properties. The RCRA Subtitle C Cell material specifications must at least meet the minimum values specified herein; but may in some cases be more stringent.

3. FILTRATION EVALUATION RESULTS

The filtration criteria used for the drainage layer design are presented below in Table 1, followed by a description justifying selection of the required design values.

Table 1. Filtration Criteria for Geotextile Components (adapted from Christopher and Holtz, 1984; Giroud, 1982; Koerner et al., 1994; and USEPA, 1987)

1. Retention Criterion

1.1. Soils with less than 50% particles < 0.075 mm (US Sieve No. 200)

Density index of the soil (Relative density)		Linear coefficient of uniformity of the soil	
		$1 < C'_u < 3$	$C'_u > 3$
loose soil	$I_D < 35\%$	$O_{95} < C'_u\, d_{50}$	$O_{95} < \frac{9}{C'_u} d_{50}$
medium dense soil	$35\% < I_D < 65\%$	$O_{95} < 1.5\, C'_u\, d_{50}$	$O_{95} < \frac{13.5}{C'_u}\, d_{50}$
dense soil	$I_D > 65\%$	$O_{95} < 2\, C'_u\, d_{50}$	$O_{95} < \frac{18}{C'_u} d_{50}$

1.2. Soils with more than 50% particles < 0.075 mm (US Sieve No. 200)
O_{95} £ 210 mm (US Sieve No. 70)

2. Permeability Criterion

2.1. Critical and/or Severe Applications
$k_{geotextile} > 10\ k_{soil}$

2.2. Noncritical and Nonsevere Applications
$k_{geotextile} > k_{soil}$

3. Anti-Clogging Criterion

Nonwoven geotextiles: porosity, $n_g > 30\%$

Notes:
- O_{95} is the apparent opening size (AOS) of the geotextile
- C'_u = linear coefficient of uniformity = $\sqrt{d'_{100}/d'_0}$
  where d'_{100} and d'_0 are the top and bottom extremities, respectively, of a line drawn through the soil particle-size distribution curve and tangent at d_{50}.
- d_{50} and d_{85} are soil particle sizes for which 50% and 85%, respectively, of particles are finer by weight
- I_D = relative density or density index = $(e - e_{min})/(e_{max} - e_{min})$, where e = soil void ratio; e_{min} = soil minimum void ratio, and e_{max} = soil maximum void ratio
- $k_{geotextile}$ = geotextile hydraulic conductivity; k_{soil} = soil hydraulic conductivity
- porosity, n_g (dimensionless) is calculated as follows: $n_g = 1 - m_g/(\rho_g t_g)$, where: m_g = geotextile mass per unit area, ρ_g = polymer density, and t_g = geotextile thickness.

3.1 Geotextile Retention

The geotextile must have openings that are small enough to retain fine-grained soil particles to avoid clogging or flow capacity reduction of the drainage material that it filters. Therefore, the apparent opening size (AOS, hereafter referred to as O_{95}) of the geotextile must be less than a required maximum value. The retention criterion is given in Table 1.

The geocomposite drainage layer in the leachate collection system will be overlain by a protective cover that is composed of impacted site soils which can be generally classified as low plasticity clay. It is assumed that this material will have more than 50% particles finer than 0.075 mm (U.S. Sieve No. 200). As shown in Table 1, for soils classified as clays, the geotextile retention criterion is as follows:

$$O_{95} \leq 210\ \mu m \text{ (U.S. Sieve No. 70)}$$

The range of geotextile mass per unit areas anticipated for use as a filtration layer or drainage layer component are 6 to 16 oz/yd^2 (200 to 540 g/m^2). Typical O_{95} values for 6 to 16 oz/yd^2 geotextiles on the current market range from 90 to 210 μm (IFAI, 2008); thus, products are available that can meet this specification.

3.2 Geotextile Permeability

The geotextile must have openings that are large enough to allow liquid to pass through the retained soil/geotextile interface without significant flow impedance. Thus, the hydraulic conductivity or permeability of the geotextile must be greater than a minimum required value. The permeability criterion is given in Table 1. For severe or critical applications, the hydraulic conductivity of the geotextile, $k_{geotextile}$, should be more than ten times greater than the hydraulic conductivity of the retained soil, k_{soil}.

The material retained by the geotextile component of the geocomposite drainage layer on the floor and the side slope is impacted site soils. Given the importance of long-term function of the drainage layers, the geotextile components are designed so that:

$$(k_{geotextile} > 100\ k_{waste}).$$

The hydraulic conductivity was assumed to be 1.6×10^{-6} for the impacted site soils (consistent with moderately compacted mixture of low- and high-plasticity clay material for calculation purposes). Therefore, the geotextile permeability criterion is as follows:

$$k_{geotextile} > 100 \times (1.6 \times 10^{-6}\ cm/s) = 1.6 \times 10^{-4}\ cm/s$$

Note that some manufacturers report the permeability property as "permittivity" (Ψ), which is defined as $\Psi = k/t$. Based on the range of geotextile mass per unit areas and thicknesses anticipated for the project (6 to 16 oz/yd^2 (200 to 540 g/m^2) and 1.3 to 5.7 mm, respectively), typical $k_{geotextile}$ values (calculated from typical permittivities and thicknesses) for needle punched non-woven geotextiles are 0.2 to 0.4 cm/sec. Therefore, needle punched non-woven geotextiles within the anticipated range for this project are well above the minimum required permeability value recommended to prevent excessive flow impedance or pore-water pressure development for both types of retained materials.

3.3 Geotextile Anti-Clogging

The geotextile filter must have enough openings so that blocking some of them will not significantly clog the geotextile and inhibit flow into the geonet. Thus, the porosity of the geotextile must be greater than a required minimum value. The clogging criterion is given in Table 1. As shown in Table 1, for non-woven geotextiles, the geotextile porosity n_g is required to be:

$$n_g > 30\%$$

The clogging criterion requirements apply for the geotextile component of the geocomposite drainage layer. Geotextile porosity is not a property that is directly measured or reported by manufacturers; however, it can be calculated as indicated in Table 1. Typical resulting n_g values

for non-woven geotextiles are 50 to 95%. Based on the geotextile density of polypropylene or polyethylene and the range of mass per unit areas and thicknesses anticipated for the project (6 to 16 oz/yd2 (200 to 540 g/m2) and 1.3 to 5.7 mm, respectively), the calculated ng values range from approximately 80% to 90%, which is well in excess of the minimum required porosity required to prevent clogging.

4. SURVIVABILITY EVALUATION RESULTS

Survivability refers to the ability of the geotextile to withstand the stresses during installation and handling in the field. The survivability criteria used for the drainage layer design are presented below in Tables 2 and 3 using a two-step method outlined by GRI-GT13 (2004), followed by a discussion on the assumptions used to select the required design values.

Table 2. Required Degree of Survivability as a Function of Subgrade Conditions and Construction Equipment (GRI-GT13)*

Subgrade Conditions	Low ground-pressure equipment (£ 25 kPa)	Medium ground-pressure equipment (> 25 kPa, £ 50 kPa)	High ground-pressure equipment (> 50 kPa)
Subgrade has been cleared of all obstacles except grass, leaves, and fine wood debris. Surface is smooth and level so that any shallow depressions and humps do not exceed 450 mm in depth or height. All larger depressions are filled. Alternatively, a smooth working table may be placed.	Low	Moderate	High
Subgrade has been cleared of obstacles larger than small to moderate-sized tree limbs and rocks. Tree trunks and stumps should be removed or covered with a partial working table. Depressions and humps should not exceed 450 mm in depth or height. Larger depressions should be filled.	Moderate	High	Very High
Minimal site preparation is required. Trees may be felled, delimbed, and left in place. Stumps should be cut to project not more than ± 150 mm above subgrade. Fabric may be draped directly over the tree trunks, stumps, large depressions and humps, holes, stream channels, and large boulders. Items should be removed only if placing the fabric and cover material over them will distort the finished road surface.	High	Very High	Not Recommended

* Recommendations are for 150 to 300 mm initial lift thickness. For other initial lift thicknesses:

300 to 450 mm: reduce survivability requirement one level;
450 to 600 mm: reduce survivability requirement two levels;
> 600 mm: reduce survivability requirement three levels

For special construction techniques such as prerutting, increase the fabric survivability requirement one level.
Placement of excessive initial cover material thickness may cause bearing failure of the soft subgrade.

As shown above, the degree of survivability is first evaluated using Table 2 with the anticipated installation conditions. The following conditions are conservatively assumed to apply: (i) smooth and level subgrade condition; (ii) initial lift thickness of protective cover placed above geotextile is 12 in.; and (iii) maximum equipment ground pressure of 5 psi (35 kPa) (i.e., medium ground-pressure equipment is used). Using Table 2, a "moderate" degree of survivability is used.

Table 3. GRI-GT13 Geotextile Strength Property Requirements

			Geotextile Classification (1)					
			Class 1 (high)		**Class 2 (moderate)**		Class 3 (low)	
Tests	Test Methods	Units	Elongation < 50%	Elongation ³ 50%	Elongation < 50%	**Elongation ³ 50%**	Elongation < 50%	Elongation ³ 50%
Grab strength	ASTM D 4632	N	1400	900	1100	**700**	800	500
Trapezoid Tear strength	ASTM D 4533	N	500	350	400	**250**	300	180
CBR Puncture strength	ASTM D 6241	N	2800	2000	2250	**1400**	1700	1000
Permittivity	ASTM D 4491	s^{-1}	0.02	0.02	0.02	**0.02**	0.02	0.02
Apparent opening size	ASTM D 4751	mm	0.6	0.6	0.6	**0.6**	0.6	0.6
Ultraviolet stability (2)	ASTM D 4355	% Ret. @ 500 hrs	50	50	50	**50**	50	50

Notes: (1) All values are MARV except UV stability (which is a minimum value) and AOS which is a maximum value).

(2) Evaluation to be on 50 mm strip tensile specimens after 500 hours exposure.

In the second step, the minimum required values for the mechanical properties of the geotextile are established from Table 3 based on the "moderate" or "Class 2" survivability requirement. The chart provides minimum required values for two ranges of geotextile extensibility. Values were selected for the more extensible range because this range is applicable to non-woven materials that are required for the geotextile. These survivability requirements apply for the geotextile component of the geocomposite drainage layer.

5. CONCLUSIONS

Based on the evaluations herein, the following specifications are recommended for the geotextile component of the geosynthetic drainage layer and the geotextile filter fabric.

- Retention and Filtration of Geotextile Components:
  - Apparent Opening Size, $O_{95} \leq 210$ mm (U.S. Sieve No. 70)
  - Geotextile Water Permeability, $k_{geotextile} \geq 1.9 \times 10^{-4}$ cm/s for geotextile components of the geocomposite overlain by the impacted soil protective cover
- Survivability (Mechanical) Properties of Geotextile Components:
  - Grab Strength = 700 N (157 lbs)
  - Trapezoid Tear Strength = 250 N (56 lbs)
  - CBR Puncture Strength = 1400 N (315 lbs)

6. REFERENCES

Christopher, B.R., and Holtz, R.D., "*Geotextile Engineering Manual*", FHWA-DTFH61-80-C-00094, 1984.

Geosynthetic Research Institute (GRI), "Standard Specification for Test Methods and Properties for Geotextiles Used as Separation Between Subgrade Soil and Aggregate", *"GRI Standard GT-13"*, 2004.

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Koerner, G.R., Koerner, R.M., and Martin, J.P., "Design of Landfill Leachate-Collection Filters", *ASCE Journal of Geotechnical Engineering*, Vol. 120, No.10, October 1994, pp. 1792-1803.

USEPA, "*Background Document: Proposed Liner and Leak Detection Rule*", EPA\530-SW-87-015, Prepared by GeoServices Inc., May 1987, 526 p.

LCS AND LDS DRAINAGE LAYER DESIGN

Written by: **A. Brown** Date: **7/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT** Project: **Malone Superfund Site** Project No.: **TXL0299** Phase No.: **02**

LEACHATE COLLECTION SYSTEM (LCS) AND LEAK DETECTION SYSTEM (LDS) DRAINAGE LAYER DESIGN

GEOSYNTEC CONSULTANTS, INC.
TEXAS ENGINEERING FIRM
REGISTRATION NO. F-1182

SEALED FOR CALCULATION PAGES
1 THROUGH 9

1. PURPOSE

The purpose of this calculation package is to present the design of the geosynthetic drainage layer of the leachate collection system (LCS) and leak detection system (LDS) for the Malone Service Company Superfund Site RCRA Subtitle C Cell. As shown on the engineering details presented on the design drawings, the geocomposite drainage layers will be composed of an HDPE geonet core with a needle punched non-woven geotextile bonded to its top and bottom surfaces (i.e., a double-sided geocomposite). It is important to note that this calculation package does not limit the type of geocomposite to single-sided or double-sided; instead a required index transmissivity will be calculated herein for each design case, irrespective of the type of geocomposite drainage product.

The items evaluated in this design evaluation include: hydraulic capacities of the geosynthetic drainage layers and testing conditions for verifying that the required capacities are achieved.

2. METHODS OF ANALYSIS

The drainage layer hydraulic capacity design evaluation is performed using the design-by-function concept presented by Koerner (2005) and based on Darcy's equation (flow rate = hydraulic conductivity × hydraulic gradient × cross-sectional area of flow) for hydraulic flow in porous, saturated media. The approach herein then follows the design methodologies presented in Giroud et al. (2000) and GRI-GC8 (2001).

The design method involves the following steps:

Step 1) Calculate the required (design) transmissivity (q_{req}) based on results of leachate generation calculations using the USEPA Hydrologic Evaluation of Landfill Performance (*HELP*) model.

Step 2) Apply a global factor of safety (FS) to find the allowable flow rate and corresponding "Long-Term In-Soil" (LTIS) transmissivity (q_{LTIS}).

Step 3) Apply partial reduction factors (RFs) for creep, chemical clogging, and biological clogging to account for the long-term decrease in flow capacity behavior, and calculate the baseline flow rate and corresponding baseline transmissivity (q_{100}).

Step 4) Determine the critical operational case for q_{100} by comparing required q_{100} to typical q_{100} for biplanar geocomposites at various loading conditions.

Step 5) Identify GRI-GC8 test conditions to measure q_{100}. The resulting q_{100} from Step 4 is a product specification for the baseline laboratory test transmissivity that should be achieved if tested in accordance with GRI-GC8, Part 6 (2001). Therefore, it is necessary to identify test conditions which simulate site-specific loading conditions and boundary conditions.

Step 6) Calculate the index transmissivity that corresponds to the baseline transmissivity from previous steps. Geocomposite manufacturers typically provide product index transmissivities based on laboratory tests in which the drainage layer is sandwiched between two steel plates as opposed to site specific boundary conditions. The index transmissivity is determined by applying a reduction factor to q_{100} to account for geotextile/soil intrusion.

3. HYDRAULIC CAPACITY EVALUATION

Step 1) Calculate Required (Design) Transmissivity, q_{req}

As presented in Leachate Generation Rates and Head on Liner calculation package, the *HELP* model was used to calculate the required (design) in-plane hydraulic conductivity and equivalent transmissivity of the leachate drainage layer. The required transmissivity is based on maintaining the peak daily average head on the liner less than or equal to the approximate thickness of the drainage layer. The required (design) transmissivity, q_{req}, was calculated for each operational condition, and the results are repeated below.

Case Designation	Operational Condition	Waste + Protective Cover Thickness (ft)	Final Cover Thickness (ft)	Design Transmissivity q_{req} (m^2/s)
IN	Initial	6	0	1.9×10^{-4}
INTERM	Intermediate	16	0	1.9×10^{-4}
FNC	Final Waste - No Cover	24	0	1.9×10^{-4}
FC	Final Closure (Liner System)	24	1.5	5.1×10^{-7}
FC-S	Final Closure (Cover System)	0	1.5	3.8×10^{-5}

Step 2) Calculate Allowable "Long Term In Soil" Transmissivity, q_{LTIS}

The allowable "Long Term In Soil" transmissivity, q_{LTIS} is calculated by applying a factor of safety to increase the minimum required transmissivity. For geocomposite drainage layers, a factor of safety (FS) of 2 was assumed in the analysis.

$$q_{LTIS} = q_{req} * FS \quad \text{(Eqn. 1)}$$

The q_{LTIS} was calculated for each operational condition, as shown below.

Case	θ_{req} (m^2/s)	θ_{LTIS} (m^2/s)
IN	1.9×10^{-4}	3.8×10^{-4}
INTERM	1.9×10^{-4}	3.8×10^{-4}
FNC	1.9×10^{-4}	3.8×10^{-4}
FC	5.1×10^{-7}	1.0×10^{-6}
FC-S	3.8×10^{-5}	7.5×10^{-5}

Step 3) Calculate Baseline Geocomposite Transmissivity, q_{100}

Factors which account for additional long-term transmissivity reduction due to intrusion, creep, chemical clogging, and biological clogging were applied to determine the minimum baseline product transmissivity, q_{100}, for laboratory testing results as shown in Eqns. 2 and 3.

$$\theta_{LTIS} = \frac{\theta_{100}}{RF_{CR}RF_{CC}RF_{BC}} \quad \text{(Eqn. 2)}$$

Where RF_{CR} = reduction factor for creep, RF_{CC} = reduction factor for chemical clogging and/or precipitation of chemicals, and RF_{BC} = reduction factor for biological clogging.

Creep is the long-term reduction in thickness of the drainage layer under a sustained compressive stress. For leachate collection systems, Koerner (2005) recommends that reduction factors for creep range from 1.4 to 2.0. For the final cover condition (Cases FNC and FC), the reduction factor for creep is assumed to be 1.6. The reduction factor for creep for initial case (Case IN) is assumed to be 1, and then increased to 1.4 for the intermediate case (Case INTERM). For the final cover system drainage layer (Case FC-S), the reduction factor for creep was assumed to be 1.4.

GRI (2001) provides guidance for clogging reduction factors for leachate collection systems. Chemical and biological clogging is expected to increase over time as leachate passes through the geocomposite. Thus, the reduction factors for clogging are assumed to increase from initial operational conditions through final cover conditions. GRI (2001) recommends a chemical clogging reduction factor between 1.5 and 2.0 and a biological clogging reduction factor between 1.1 and 1.3 at final conditions. Based on recommendations by GRI, the chemical clogging reduction factors are assumed to increase from 1.0 to 2.0 from initial through final cover conditions. For biological clogging, the assumed reduction factors increase from 1 to 1.2 from initial through final cover conditions for liner system drainage layers. For the final cover system drainage layer (Case FC-S), the reduction factor for chemical clogging was assumed to be equal to 1.1, and the reduction factor for biological clogging was assumed to be 3.0 (due to the relatively small depths of cover soil and the proximity of vegetation).

Rearranging Eqn. 2 and substituting q_{LTIS} and the reduction factors above, we obtain the following equation:

$$q_{100} = q_{LTIS}\ RF_{CR}\ RF_{CC}\ RF_{BC} \qquad \text{(Eqn. 3)}$$

The q_{100} was calculated for each operational condition, as shown below.

Cases	θ_{LTIS} (m^2/s)	RF_{CR}	RF_{CC}	RF_{BC}	RF_{total}	θ_{100} (m^2/s)
IN	3.8×10^{-4}	1.00	1.00	1.00	1.00	3.8×10^{-4}
INTERM	3.8×10^{-4}	1.40	1.70	1.10	2.62	9.8×10^{-4}
FNC	3.8×10^{-4}	1.60	1.90	1.20	3.65	1.4×10^{-3}
FC	1.0×10^{-6}	1.60	2.00	1.20	3.84	3.9×10^{-6}
FC-S	7.5×10^{-5}	1.40	1.10	3.00	4.62	3.5×10^{-4}

Step 4) Calculate the Critical Operational Case for q_{100}

Geosyntec contacted GSE Lining Technology, Inc. to obtain q_{100} data for a common biplanar geocomposite on the market. The data correspond to the product, FabriNet, a geocomposite with non-woven geotextile on both sides of the geonet. This does not constitute specification or

endorsement of this product; it is merely intended to compare the required transmissivities to a commercially available product to check reasonableness of the design and availability of products. The TN 270-2-8 geocomposite transmissivity was measured at a gradient of 0.1 while sandwiched between sand and a geomembrane for a seating time of 100 hours under four different normal stresses.

To compare the required q_{100} to the typical q_{100} on the market, the normal stress expected for each operational condition must be calculated. The stress can be determined from the thickness of fill to be placed above the drainage layer as follows:

$$p = \gamma_{waste} h_{waste} + \gamma_{cover} h_{cover} \quad \text{(Eqn. 4)}$$

where: p represents the normal stress, γ represents the density of the waste or the protective cover soil, and h represents the thickness of the waste or protective cover soil. The stress was calculated for each operational condition, as shown below.

Case	$h_{prot.\ cover}$ (ft)	$\gamma_{prot.\ cover}$ (pcf)	h_{waste} (ft)	γ_{waste} (pcf)	$h_{final\ cover}$ (ft)	$\gamma_{final\ cover}$ (pcf)	Stress (psf)	θ_{100} (m^2/s)
IN	1	120	5	80	--	--	520	3.8×10^{-4}
INTERM	1	120	15	80	--	--	1320	9.8×10^{-4}
FNC	1	120	23	80	--	--	1960	1.4×10^{-3}
FC	1	120	23	80	1.5	120	2140	3.9×10^{-6}
FC-S	--	--	--	--	1.5	120	180	3.5×10^{-4}

The required (minimum) q_{100} is plotted versus the calculated stress in Figure 1. The expected q_{100} data for a typical biplanar geocomposite is shown for reference. As shown in Figure 1, the required q_{100} for all operational cases are less than q_{100} for a typical biplanar geocomposite at corresponding stress conditions. Therefore, the geocomposite should provide adequate hydraulic capacity for operational conditions. By inspection of Figure 1, the most critical operational condition for the geocomposite drainage layer is the final waste condition with no cover (FNC). The critical condition occurs where the difference between required q_{100} and measured q_{100} is the least. The required q_{100} is 1.4×10^{-3} m^2/s and the applied stress is approximately 1,960 psf.

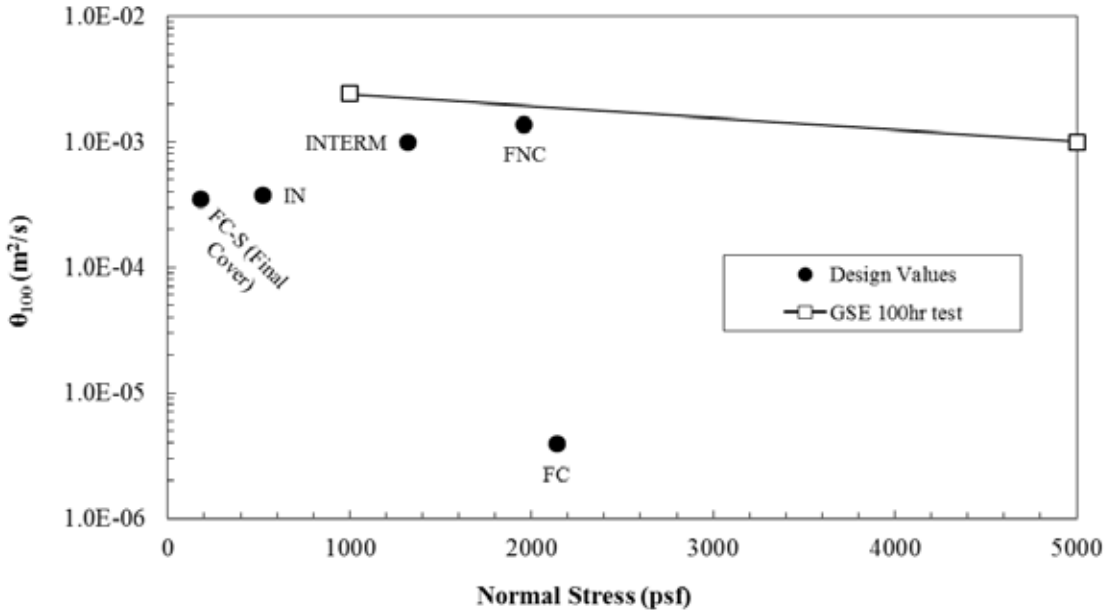

Figure 1. Comparison of Required q_{100} to Typical q_{100} Test Results at Various Normal Stresses. Note: The typical product information shown does not constitute an endorsement of these products, nor does this require the use of any specific manufacturer or product. This information is presented for comparison purposes only.

Step 5) Identify Site-Specific Conditions for Evaluating q_{100}

The testing conditions to be used in evaluating q_{100} using GRI Standard GC8, Part 6 are: (i) the testing configuration (i.e., stratum configuration); (ii) the applied stress; and (iii) the hydraulic gradient. These conditions are specified below.

- The recommended testing configuration for transmissivity testing of the leachate drainage layer should consist of a 60-mil HDPE geomembrane on one side of the geocomposite specimen (to simulate site-specific liner design) and a clay type of soil on the other side of the geocomposite specimen (to simulate the protective cover).
- The stress to be applied in testing the leachate drainage layer should be equivalent to the stress at the most critical condition found in Step 4. As noted in Step 4, the most critical operational condition for the geocomposite occurs at final condition with no cover, Case FNC. Therefore, the stress on the leachate drainage layer geocomposite material to be used in determining q_{100} is 1,960 psf, and the stress on the final cover geocomposite to be used in determining q_{100} is 180 psf.

- The leachate collection and leak detection system geocomposite drainage layer slopes at about 0.4% on the cell floor. Therefore, the hydraulic gradient to be used in determining q_{100} for the geocomposite is 0.004.
- The final cover system geocomposite drainage layer slopes at an average value of approximately 3% on the shallowest sideslopes. Therefore, the hydraulic gradient to be used in determining q_{100} for the geocomposite is 0.03.

Step 6) Determine Index Transmissivity, q_{INDEX}, Based on q_{100}

While the q_{100} given above is suitable for use as a specification if desired, it is usually more convenient to report the transmissivity between two steel plates for a short duration test since manufacturers of geocomposite drainage materials often present the hydraulic capacities of their product in this manner. These transmissivities are usually higher than those that would be obtained using the site specific boundary conditions of soil on one side and a geomembrane on the other side. This is because the short duration test does not completely account for the time-delayed intrusion of the geotextile into the transmissive core resulting from the deformation of the geotextile under sustained loading. Additionally, the steel plate boundary condition of the short duration test will not account for a reduction in transmissivity due to particle migration into the transmissive core.

To compare the specified q_{100} of the leachate drainage layer with index values reported by the manufacturer, factors can be applied to account for the reduction of the transmissivity that may be experienced due to intrusion and particulate clogging when testing the drainage layer with boundary materials other than steel plates. The index transmissivity, q_{INDEX}, which accounts for intrusion and particulate clogging, can be determined as shown in Eqn. 5:

$$q_{INDEX} = q_{100} * RF_{INT} RF_{PC} \quad \text{(Eqn. 5)}$$

Koerner (2005) recommends using an intrusion reduction factor (RF_{INT}) between 1.5 and 2.0. For the leachate drainage layer geocomposite, an intrusion factor of 1.5 was assumed for initial conditions and 2.0 for final conditions. For the final cover system drainage geocomposite, which is anticipated to be at comparatively low overburden stresses in the field, the intrusion factor was assumed to be 1.4. The geotextile is expected to adequately retain particulates to avoid potential clogging of the transmissive core, as discussed in the Geotextile Filter Design calculation package; however, a particulate clogging reduction factor (RF_{PC}) of 1.1 is applied.

The index transmissivity, q_{INDEX}, for the leachate collection system drainage geocomposite at the critical condition specified in step 4 (final waste condition FNC) is found to be:

$$q_{INDEX,\ LINER} = 1.4\times10^{-3}\ (m^2/s) \times 2.0 \times 1.1$$
$$q_{INDEX,\ LINER} = 3.0\times10^{-3}\ m^2/s$$

For the final cover system drainage geocomposite at the critical condition specified in step 4 (final waste condition FC-S), the index transmissivity, q_{INDEX}, is found to be:

$$q_{INDEX,\ COVER} = 3.5\times10^{-4}\ (m^2/s) \times 1.4 \times 1.1$$
$$q_{INDEX,\ COVER} = 5.3\times10^{-4}\ m^2/s$$

Comparison of Calculated Index Transmissivity to Minimum Regulatory Requirements

According to 40 CFR §264.301, the minimum transmissivity for a geosynthetic material used as a drainage layer in the liner system of a landfill disposing hazardous waste is 3×10^{-5} m^2/s. The calculated index transmissivity as presented in the above analysis is greater than that required by regulation. Therefore, the calculated transmissivity is more stringent and governs as a minimum requirement.

4. CONCLUSIONS

Based on the evaluations herein, the following specifications are recommended:

- For the leachate collection system drainage layer geocomposite, $q_{INDEX} = 3.0\times10^{-3}$ m^2/s (when tested between two steel plates with an applied stress of 1,960 psf at a gradient of 0.004) based on the site-specific design calculations.
- Using the same methodology for the leak detection system drainage layer as was presented herein for the leachate collection system drainage layer, but for the smaller anticipated flows in the LDS, $q_{INDEX} = 3.5\times10^{-4}$ m^2/s (when tested between two steel plates with an applied stress of 1,960 psf at a gradient of 0.004) based on the site-specific design calculations.
- For the final cover system drainage layer geocomposite, $q_{INDEX} = 5.3\times10^{-4}$ m^2/s (when tested between two steel plates with an applied stress of 180 psf at a gradient of 0.03) based on the site-specific design calculations.
- An index transmissivity equal to or greater than this value should be specified.

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LCS AND LDS PIPE DESIGN

Written by: **A. Brown** Date: **7/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT** Project: **Malone Superfund Site** Project No.: **TXL0299** Phase No.: **02**

LCS AND LDS PIPES DESIGN

GEOSYNTEC CONSULTANTS, INC.
TEXAS ENGINEERING FIRM
REGISTRATION NO. F-1182

SEALED FOR CALCULATION PAGES
1 THROUGH 24

1. INTRODUCTION

The purpose of this analysis is to evaluate the hydraulic capacity of the leachate collection system (LCS) and leak detection system (LDS) pipes and to evaluate the ability of the pipes to resist the estimated applied loads with adequate factors of safety at the Malone Service Company RCRA Subtitle C Cell. The leachate collection and leak detection pipes within the landfill subcells will be 6" and 4" diameter standard dimension ratio (SDR)-11 (maximum) perforated high-density polyethylene (HDPE), respectively. The riser pipes at the leachate collection and leak detection sumps within the subcells will be a minimum of 18" and 12" diameter SDR-17 (maximum) HDPE, respectively.

The function of leachate collection pipes is to convey leachate collected by the leachate drainage layer to the leachate sump. Similarly, leak detection pipes will convey liquid from the leak detection layer to the leak detection sump. The collection pipes must have adequate hydraulic capacity to carry leachate collected by the leachate drainage layer to the sump and should have adequate structural resistance to withstand the estimated applied loads.

The riser pipes will extend from the sumps to the top of the perimeter sideslope. A pump will be placed inside the riser pipe in each sump to transfer the liquid from the sump to the leachate transmission system (LTS). The riser pipes must have adequate structural resistance to withstand the estimated applied loads.

2. METHODS OF ANALYSES

2.1 Pipe Hydraulic Capacity Evaluation

The LCS pipe flow capacities should be greater than the leachate flow entering the pipe. The pipe flow capacity is calculated using Manning's equation for a fully flowing pipe as follows:

$$Q_p = \frac{1.486 {R_h}^{2/3} {i_p}^{0.5} A_p}{n} \quad \text{(Eqn. 1)}$$

where:

Q_p = pipe flow capacity, cfs;
R_h = hydraulic radius, ft (i.e., ratio of the flow area to the perimeter of the wetted area, $\frac{B_i}{4}$, where B_i is pipe inner diameter, ft);
i_p = hydraulic gradient (i.e., slope of the pipe);
A_p = cross-sectional area of the pipe, ft^2; and
n = Manning's roughness coefficient.

For a pipe with a circular cross section that is flowing full, Manning's equation assumes steady, uniform, and fully-turbulent conditions. A design n value of 0.009 for HDPE pipe was chosen from Table 1 (CPChem, 2003).

The maximum flow rate of leachate entering the leachate collection corridor and the leak detection system pipe of the RCRA Subtitle C Cell was calculated using impingement rates provided in Table 1 of the Leachate Generation Rates and Head on Liner calculation package. The peak daily impingement rate for the most critical condition, initial condition Case IN, was 1,533 gallons per acre per day (gpad) for the leachate collection corridor. For the largest proposed subcell, serving an area of approximately 14.4 acres, the peak daily flow rate was calculated to be approximately 22,079 gallons per day (gpd) for the leachate collection corridor. The maximum flow rate expected from the RCRA Subtitle C cell is compared to the capacity of the leachate corridor collector pipe to ensure that the calculated collector pipe flow capacity is greater than the calculated maximum expected flow rates for all subcells.

Because substantially less flow will be experienced by the LDS pipe compared to the LCS pipe, a detailed evaluation of LDS capacity was not necessary, and it can be concluded by inspection that the LDS pipe capacity will be adequate for the much smaller flows expected.

2.2 Pipe Strength Evaluation

Four potential strength failure mechanisms for plastic pipes are: (i) wall crushing; (ii) wall buckling; (iii) excessive ring deflection; and (iv) excessive bending strain. These mechanisms are evaluated below using methods presented in the technical literature for flexible plastic pipes [Uni-Bell PVC Pipe Association (Unibell), 1991; Chevron Phillips Chemical Company

(CPChem), 2003]. The design methods for flexible plastic pipe are applicable for both PVC and HDPE pipes (U.S. Army Corps of Engineers, 1997).

Stress on Leachate Collection, Leak Detection, and Riser Pipes

Stresses applied to the pipes are estimated for the post-closure condition since loads during construction are expected to be significantly lower than the post-closure stresses. During the post-closure condition, the stress applied to the pipe is due to the overburden materials above the pipe (i.e., waste material and daily, intermediate, and final cover soils). This stress is calculated as follows:

$$\sigma_{max} = \gamma_p D_p \quad \text{(Eqn. 2)}$$

where:

σ_{max} = stress on the pipe, psf;
γ_p = average unit weight of the overburden materials, pcf; and
D_p = thickness of the overburden materials, ft.

The influence of holes on the pipe stress is not normally accounted for in the design process (Bonaparte et al., 2002) and is not done so here. Instead, perforation locations that have been demonstrated to be less critical in terms of stress concentrations (Brachman and Krushelnitzky, 2002) have been specified (i.e., perforations are located at the pipe shoulders and haunches).

The structural resistance of the 4" and 6" diameter leak detection and leachate collection pipes is evaluated under loading from approximately 26 ft of overburden material (the greatest waste thickness plus the overlying liner system component and final cover system materials).

The structural resistance of the 12" and 18" diameter riser pipes is evaluated under loading from approximately 23 ft of overburden material (the greatest waste thickness at the sump plus the overlying liner system component and final cover system materials).

Wall Crushing

Wall crushing can occur when the stress in the pipe wall, due to external vertical pressure, exceeds the compressive strength of the pipe material. The factor of safety against pipe wall crushing may be calculated using the following equation:

$$FS_{wc} = \frac{2\sigma_y}{(SDR-1)\sigma_{max}} \quad \text{(Eqn. 3)}$$

where:

FS_{wc} = factor of safety against pipe wall crushing;
s_y = compressive yield strength of the pipe, psf;
SDR = standard dimension ratio of the pipe, i.e., the outer diameter of the pipe divided by the wall thickness of the pipe; and
s_{max} = maximum stress applied to the pipe, psf.

Wall Buckling

Wall buckling (a longitudinal wrinkling in the pipe wall) can occur when the external vertical pressure exceeds the critical buckling pressure of the pipe/bedding aggregate system. The factor of safety against pipe wall buckling may be calculated using the following equation:

$$FS_{wb} = \frac{1.2}{\sigma_{max}}\left[\frac{E'E}{(SDR)^3}\right]^{1/2} \quad \text{(Eqn. 4)}$$

where:

FS_{wb} = factor of safety against pipe wall buckling;
s_{max} = maximum stress applied to the pipe, psi;
E¢ = f (E_s, n, k) = modulus of soil reaction for pipe bedding material, psi;
E = modulus of elasticity of the pipe material, psi; and
SDR = standard dimension ratio of the pipe.

The modulus of soil reaction, E¢ for pipe bedding is a representative parameter of soil stiffness, which is related to the overburden stress. The modulus of soil reaction is calculated using the Young's modulus of the pipe bedding material (E_s), Poisson's ratio of the pipe bedding material (n), and an empirical factor (k) based on test data.

The following equation was used to calculate the constrained modulus of the bedding material:

$$M_s = \frac{E_s(1-v)}{(1+v)(1-2v)} \quad \text{(Eqn. 5)}$$

where:

M_s = constrained modulus of bedding material, psi;
E_s = Young's modulus of bedding material, psi; and
n = Poisson's ratio of bedding material.

The Young's modulus and Poisson's ratio were taken from data presented by Selig (1990) for soils at various overburden stress levels. For the leachate collection and leak detection pipe analysis, the Young's modulus and Poisson's ratio values are based on a gravel bedding material

(i.e., having a classification of GW or GP as defined by the Unified Soil Classification System (USCS)) compacted to 85 percent ASTM D698, as considered in the Selig (1990) table (Table 2). It is assumed that this material will be an AASHTO No. 57 stone or similar material. The calculations for the riser pipes assume a well-graded granular material (having a USCS classification of SP, SW, GP, or GW) compacted to 85 percent ASTM D698.

The modulus of soil reaction can then be calculated based on the constrained modulus of the bedding material (M_s) and an empirically derived factor (k).

$$E' = k * M_s \quad \text{(Eqn. 6)}$$

where:

E¢ = modulus of soil reaction for pipe bedding material, psi;
k = empirically derived factor; and
M_s = constrained modulus of bedding material, psi.

The value of k may vary from 0.7 to 2.3 (Selig, 1990). For the analysis herein, an average value of k = 1.5 is used.

Ring Deflection

Excessive ring deflection is a horizontal over-deflection of the pipe causing a reversal of curvature of the pipe wall. This can occur if large external vertical pressures are applied to the pipe/bedding aggregate system. Excessive ring deflection can also lead to substantial loss in flow capacity. Ring deflection is calculated using the Modified Iowa Equation (Mosher, 1990):

$$\Delta X = \frac{D_L K W_c}{(EI/r^3)+(0.061E')} \quad \text{(Eqn. 7)}$$

where:

DX = horizontal deflection or change in diameter, in.;
D_L = deflection lag factor;
K = bedding constant;
W_c = Marston's prism load per unit length of pipe, psi;
E = short-term modulus of elasticity of the pipe, psi;
E' = modulus of soil reaction for bedding material, psi;
I = moment of inertia of the pipe wall per unit length, $in.^4/in.$; and
r = mean radius of the pipe $\left[\frac{D_{od}-t}{2}\right]$, in.

For PVC pipe, Uni-Bell (1997) recommends a value of 7.5 percent as the allowable ring deflection. For non-pressure heavy wall HDPE pipe, CPChem (2003) does not recommend a

specific "allowable deflection", but instead recommends the bending strain at the predicted deflection be calculated and compared to the allowable strain.

Bending Strain

When a pipe deflects under load, bending strains are induced in the pipe wall. Bending strain occurs in the pipe wall as external pressures are applied to the pipe/bedding aggregate system. Bending strain is calculated using the following equation (Mosher, 1990):

$$\varepsilon_b = f_d \frac{t\Delta y}{D^2} \quad \text{(Eqn. 8)}$$

where:

e_b = bending strain, percent;
f_d = deformation shape factor (CPChem (2003) recommends a value of 4.28 for elliptical deformation, or 6.0 to account for imperfect deformation. The conservative value of 6.0 was used in the analysis);
t = minimum wall thickness, in.;
Δy = vertical deflection, in.; and
D = mean pipe diameter, in.

The following are recommendations for allowable bending strain from the literature and manufacturers:

- an allowable bending strain of 5 percent is recommended in Wilson-Fahmy and Koerner (1994), based on ASSHTO guidelines for long term use of smooth polyethylene pipes;
- an allowable bending strain of 4.2 percent is recommended as conservative in CPChem (2003) [it is noted that strains up to 8 percent are reported in literature as acceptable for a design period of 50 years]; and
- an allowable bending strain of 3.5 percent is recommended for PVC pipe in US Army Corps of Engineers (1997).

Based on the above information, an allowable strain of 5 percent is selected for HDPE pipe.

3. CALCULATIONS

3.1 Pipe Hydraulic Capacity Calculations

The proposed collector pipe for the leachate collection system is a perforated 6 in. diameter HDPE SDR-11 pipe.

n = Manning's roughness coefficient = 0.009 (CPChem 2003)

i_p = hydraulic gradient = 0.0018 (0.18 percent slope along shallowest portion of drainage corridor)

B_i = 5.42 in / 12 in/ft = 0.4517 ft

R_h = hydraulic radius = $\frac{B_i}{4} = \frac{0.4517\ ft}{4}$ = 0.113 ft

A_p = cross-sectional area of the pipe = $\frac{\pi {B_i}^2}{4} = \frac{\pi(0.4517\ ft)^2}{4}$ = 0.16 ft^2

Based on the parameters above, the flow capacity of the 6 in. diameter pipe is calculated as follows:

$$Q_p = \frac{1.486 {R_h}^{2/3} {i_p}^{0.5} A_p}{n}$$

$$Q_p = (1.486\ ft^{0.33}/s)(0.113\ ft)^{2/3}(0.0018)^{0.5}(0.16\ ft^2) / 0.009$$

$$Q_p = 0.618\ ft^3/s = 170{,}945\ gpd$$

Given that the largest peak daily flow rate of leachate into the leachate collection corridor is calculated to be 22,058 gpd, the calculated pipe flow capacity of 170,945 gpd is predicted to have adequate capacity to convey leachate through the RCRA Subtitle C Cells leachate collection corridors with a wide margin of safety.

3.2 Pipe Strength Calculations

Pipe strength calculations were carried out for the 6" leachate collection pipe; 4" leak detection pipe; and the 12" and 18" riser pipes under expected maximum loads (at landfill final grades). In addition, the maximum height of waste that the LCS, LDS, and riser pipes can accommodate with adequate factors of safety and allowable strains were calculated. The input parameters, and calculated and allowable factors of safety, deflections, and strains are presented in Appendix 1.

4. SUMMARY AND CONCLUSIONS

4.1 Pipe Hydraulic Capacity Evaluation

The highest peak daily leachate collection rate by a single leachate collection corridor of the RCRA Subtitle C Cell is 22,079 gpd. This peak daily leachate flow rate can be conveyed to the

sump by a 6-in. diameter collection pipe that has a calculated flow capacity of 170,945 gpd. Therefore it can be concluded that the LCS pipe has adequate hydraulic capacity, with substantial factor of safety. As noted, the 4-in. diameter LDS pipe will experience a much smaller quantity of liquid in comparison to that of the 6-in diameter LCS pipe and therefore, by inspection, will have adequate hydraulic capacity.

4.2 Pipe Strength Evaluation

4" and 6"ƒ SDR-11 HDPE Leak Detection and Leachate Collection Pipes

Under the expected working stresses resulting from a total overburden of approximately 26 ft of material on top of the leachate collection and leak detection corridor, the pipe strength evaluation is summarized as follows:

- Factor of safety against pipe wall crushing, FS_{wc} = 16.6 (OK)
- Factor of safety against pipe wall buckling, FS_{wb} = 22.0 (OK)
- Ring deflection = 0.57 % (OK)
- Bending strain = 0.38 % (OK)

Also, for reference, as a back-calculation the maximum height of waste over the corridor that would result in acceptable factors of safety (i.e. FS ≥ 1.5) and allowable strains is 280 ft.

12" and 18"ƒ SDR-17 HDPE Riser Pipes (granular bedding)

Under the expected working stresses resulting from a total waste height of 23 ft on top of the riser pipes, the pipe strength evaluation is summarized as follows:

- Factor of safety against pipe wall crushing, FSwc = 11.7 (OK)
- Factor of safety against pipe wall buckling, FSwb = 12.5 (OK)
- Ring deflection = 0.60% (OK)
- Bending strain = 0.24 % (OK)

Also, for reference, as a back-calculation, the maximum height of waste over the riser pipes that would result in acceptable factors of safety (i.e. FS ≥ 1.5) and allowable strains is 180 ft.

Based on the above results, the specified pipes are anticipated to perform as designed.

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TABLES

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Client: **ENTACT** Project: **Malone Superfund Site** Project No.: **TXL0299** Phase No.: **02**

Table 1. Values of n for use with Manning's Equation (from CPChem, 2003)

Surface	*n, range*	*n, typical design*
Polyethylene pipe	0.008 – 0.011	0.009
Uncoated cast or ductile iron pipe	0.012 – 0.015	0.013
Corrugated steel pipe	0.021 – 0.030	0.024
Concrete pipe	0.012 – 0.016	0.015
Vitrified clay pipe	0.011 – 0.017	0.013
Brick and cement mortar sewers	0.012 – 0.017	0.015
Wood stave	0.010 – 0.013	0.011
Rubble masonry	0.017 – 0.030	0.021

Table 2. Modulus of Soil Reaction for Pipe Bedding Material (from Selig, 1990)

Soil Type: SW, SP, GW, GP

Stress level psi (kPa)	95% D698 E_s	95% D698 B	95% D698 ν_s	85% D698 E_s	85% D698 B	85% D698 ν_s
1 (7)	1600 (11)	2800 (19)	0.40	1300 (9)	900 (6)	0.26
5 (34)	4100 (28)	3300 (23)	0.29	2100 (14)	1200 (8)	0.21
10 (70)	6000 (41)	3900 (27)	0.24	2600 (18)	1400 (10)	0.19
20 (140)	8600 (59)	5300 (37)	0.23	3300 (23)	1800 (12)	0.19
40 (280)	13000 (90)	8700 (60)	0.25	4100 (28)	2500 (17)	0.23
60 (410)	16000 (110)	13000 (90)	0.29	4700 (32)	3500 (24)	0.28

Soil Type: GM, SM, ML, and GC, SC with < 20% fines

Stress level psi (kPa)	95% D698 E_s	95% D698 B	95% D698 ν_s	85% D698 E_s	85% D698 B	85% D698 ν_s
1 (7)	1800 (12)	1900 (13)	0.34	600 (4)	400 (3)	0.25
5 (34)	2500 (17)	2000 (14)	0.29	700 (5)	450 (3)	0.24
10 (70)	2900 (20)	2100 (14)	0.27	800 (6)	500 (3)	0 23
20 (140)	3200 (22)	2500 (17)	0.29	850 (6)	700 (5)	0.30
40 (280)	3700 (25)	3400 (23)	0.32	900 (6)	1200 (8)	0.38
60 (410)	4100 (28)	4500 (31)	0.35	1000 (7)	1800 (12)	0.41

Soil Type: CL, MH, GC, SC

Stress level psi (kPa)	95% D698 E_s	95% D698 B	95% D698 ν_s	85% D698 E_s	85% D698 B	85% D698 ν_s
1 (7)	400 (3)	800 (6)	0.42	100 (1)	100 (1)	0.33
5 (34)	800 (6)	900 (6)	0.35	250 (2)	200 (1)	0.29
10 (70)	1100 (8)	1000 (7)	0.32	400 (3)	300 (2)	0.28
20 (140)	1300 (9)	1100 (8)	0.30	600 (4)	400 (3)	0.25
40 (280)	1400 (10)	1600 (11)	0.35	700 (5)	800 (6)	0.35
60 (410)	1500 (10)	2100 (14)	0.38	800 (6)	1300 (9)	0.40

Note: Units of E_s and B are psi (MPa).

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Client: **ENTACT** Project: **Malone Superfund Site** Project No.: **TXL0299** Phase No.: **02**

FIGURES

Written by: **A. Brown** Date: **7/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT** Project: **Malone Superfund Site** Project No.: **TXL0299** Phase No.: **02**

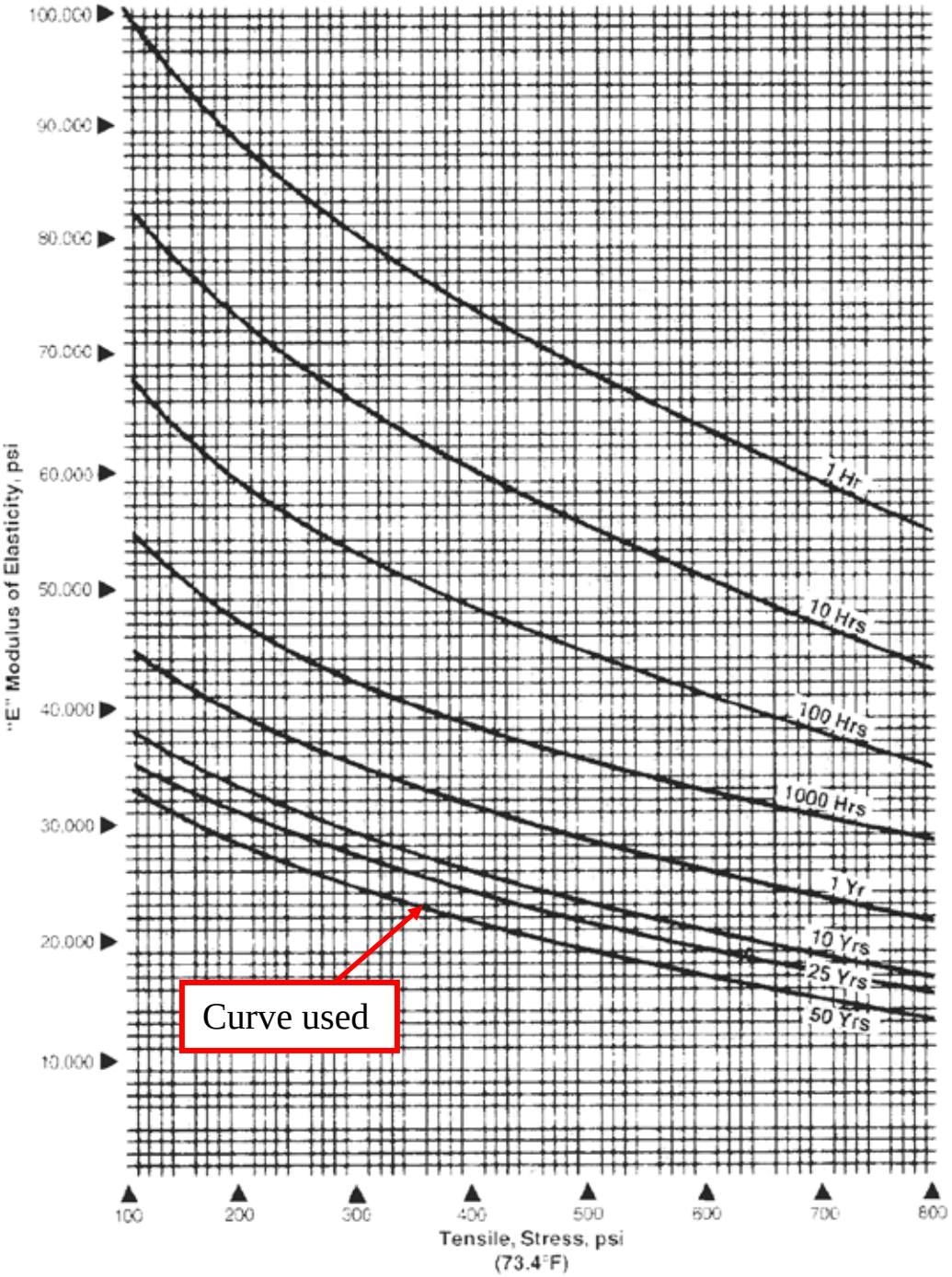

Figure 1. Time Dependent Modulus of Elasticity for Polyethylene Pipe (from Phillips 66, 1991)

Values of Bedding Constant

Bedding Angle (degrees)	K
0	0.110
30	0.108
45	0.105
60	0.102
90	0.096
120	0.090
180	0.083

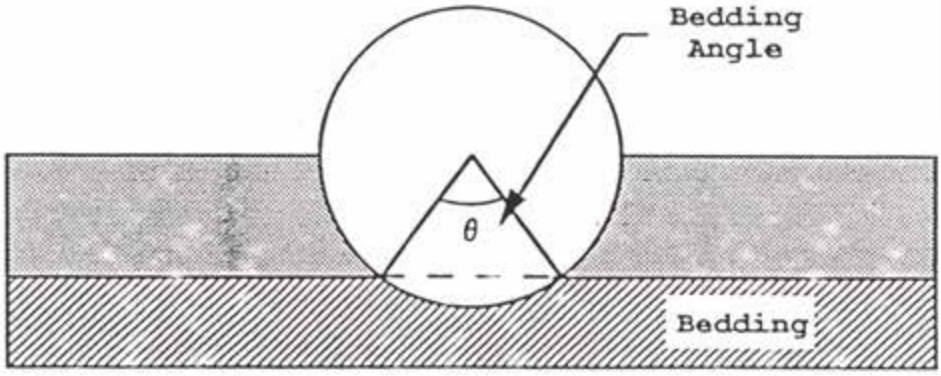

Figure 2. Bedding Constant (from Wilson-Fahmy and Koerner, 1994)

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APPENDIX 1

PIPE STRENGTH CALCULATIONS

Written by: **A. Brown** Date: **7/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT** Project: **Malone Superfund Site** Project No.: **TXL0299** Phase No.: **02**

6"ƒ SDR-11 HDPE Leachate Collection Pipe (working stress)

Malone Superfund Site - Pipe Strength Design
Performed by: A. Brown

Input Parameters

Waste

d_c =	26	ft
γ_{avg} =	100	pcf

Pipe

SDR =	11	
D_{od} =	6.625	in.
t_{min} =	0.602	in.
E =	34,017	psi
σ_y =	1500	psi
D_L =	1.25	
K =	0.083	
k =	1.5	

Bedding Soil

E_s =	2600	psi
n =	0.19	

Calculated Parameters

σ_{max} =	18.1	psi
M_s =	2854	psi
E' =	4282	psi
W_c =	120	lb/in.
I =	0.01821	$in.^4/in.$
r_{mean} =	3.01	in.
S_A =	90.3	psi

Strength Checks

Wall Crushing

$$FS_{WC} = \frac{2\sigma_y}{(SDR - 1)\sigma_{max}}$$

FS_{WC} = 16.6 ≥ 1.5

Wall Buckling

$$FS_{wb} = \frac{1.2}{\sigma_{max}} \left[\frac{E' / E}{SDR^3} \right]^{1/2}$$

FS_{wb} = 22.0 ≥ 1.5

Ring deflection (Modified Iowa Equation):

$$DX = \frac{D_L K W_c}{(EI / r^3) + (0.061 E')}$$

Change in diameter, DX = 0.04 in.
Ring deflection, DX% = 0.57 %

DX% = the ring deflection, %.
= 100(DX/D_{od})
ε_b = Bending strain, %;
Δy = Vertical deflection, in. = ΔX;
D = diameter = Mean diameter (D_{od}-t_{min}),

Pipe wall bending strain, ε_b.

$$\varepsilon_b = 6 \times \frac{t_{min} \times Dy}{D^2}$$

Dy = 0.038 in.
D = 6.02 in.

Bending strain, ε_b = 0.38 %

Allowable wall ring bending strain: from 4.2 to 8% (8% for 50 year design life) - [CPChem, 2003]

Written by: **A. Brown** Date: **7/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT** Project: **Malone Superfund Site** Project No.: **TXL0299** Phase No.: **02**

6"ƒ SDR-11 HDPE Leachate Collection Pipe (back-calculated maximum stress)

Malone Superfund Site - Pipe Strength Design
Performed by: A. Brown

Input Parameters

Waste

d_c = 280 ft
γ_{avg} = 100 pcf

Pipe

SDR = 11
D_{od} = 6.625 in.
t_{min} = 0.602 in.
E = 5,647 psi
σ_y = 1500 psi
D_L = 1.25
K = 0.083
k = 1.5

Bedding Soil

E_s = 4700 psi
n = 0.28

Calculated Parameters

σ_{max} = 194.4 psi
M_s = 6009 psi
E' = 9013 psi
W_c = 1,288 lb/in.
I = 0.01821 in.^{4}/in.
r_{mean} = 3.01 in.
S_A = 972.2 psi

Strength Checks

Wall Crushing

$$FS_{WC} = \frac{2\sigma_y}{(SDR - 1)\sigma_{max}}$$

FS_{WC} = 1.5 ≥ 1.5

Wall Buckling

$$FS_{wb} = \frac{1.2}{\sigma_{max}} \left[\frac{E' E_s}{SDR^3} \right]^{1/2}$$

FS_{wb} = 1.2 ≥ 1.5

Ring deflection (Modified Iowa Equation):

$$DX = \frac{D_L K W_c}{(EI / r^3) + (0.061 E')}$$

Change in diameter, DX = 0.22 in.
Ring deflection, DX% = 3.27 %

DX% = the ring deflection, %.
= 100(DX/D_{od})
ε_b = Bending strain, %;
Δy = Vertical deflection, in. = ΔX;
D = diameter = Mean diameter (D_{od}-t_{min}),

Pipe wall bending strain, ε_b.

$$\varepsilon_b = 6 \times \frac{t_{min} \times Dy}{D^2}$$

Dy = 0.217 in.
D = 6.02 in.

Bending strain, ε_b = 2.16 %

Allowable wall ring bending strain: from 4.2 to 8% (8% for 50 year design life) - [CPChem, 2003]

Written by: **A. Brown** Date: **7/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT** Project: **Malone Superfund Site** Project No.: **TXL0299** Phase No.: **02**

4"ƒ SDR-11 HDPE Leak Detection Pipe (working stress)

Malone Superfund Site - Pipe Strength Design
Performed by: A. Brown

Input Parameters

Waste

d_c =	26	ft
γ_{avg} =	100	pcf

Pipe

SDR =	11	
D_{od} =	4.500	in.
t_{min} =	0.409	in.
E =	34,017	psi
σ_y =	1500	psi
D_L =	1.25	
K =	0.083	
k =	1.5	

Bedding Soil

E_s =	2600	psi
n =	0.19	

Calculated Parameters

σ_{max} =	18.1	psi
M_s =	2854	psi
E' =	4282	psi
W_c =	81	lb/in.
I =	0.00571	$in.^4/in.$
r_{mean} =	2.05	in.
S_A =	90.3	psi

Strength Checks

Wall Crushing

$$FS_{WC} = \frac{2\sigma_y}{(SDR - 1)\sigma_{max}}$$

FS_{WC} = 16.6 ≥ 1.5

Wall Buckling

$$FS_{wb} = \frac{1.2}{\sigma_{max}} \left[\frac{E' E_s}{SDR^3} \right]^{1/2}$$

FS_{wb} = 22.0 ≥ 1.5

Ring deflection (Modified Iowa Equation):

$$DX = \frac{D_L K W_c}{(EI / r^3) + (0.061 E')}$$

Change in diameter, DX = 0.03 in.
Ring deflection, DX% = 0.57 %

Pipe wall bending strain, ε_b.

$$\varepsilon_b = 6 \times \frac{t_{min} \times Dy}{D^2}$$

Dy = 0.026 in.
D = 4.09 in.

Bending strain, ε_b = 0.38 %

Allowable wall ring bending strain: from 4.2 to 8% (8% for 50 year design life) - [CPChem, 2003]

DX% = the ring deflection, %.
= 100(DX/D_{od})
ε_b = Bending strain, %;
Δy = Vertical deflection, in. = ΔX;
D = diameter = Mean diameter (D_{od}-t_{min}),

Written by: **A. Brown** Date: **7/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT** Project: **Malone Superfund Site** Project No.: **TXL0299** Phase No.: **02**

4"ƒ SDR-11 HDPE Leak Detection Pipe (back-calculated maximum stress)

Malone Superfund Site - Pipe Strength Design
Performed by: A. Brown

Input Parameters

Waste

d_c = 280 ft
γ_{avg} = 100 pcf

Pipe

SDR = 11
D_{od} = 4.500 in.
t_{min} = 0.409 in.
E = 5,647 psi
σ_y = 1500 psi
D_L = 1.25
K = 0.083
k = 1.5

Bedding Soil

E_s = 4700 psi
n = 0.28

Calculated Parameters

σ_{max} = 194.4 psi
M_s = 6009 psi
E' = 9013 psi
W_c = 875 lb/in.
I = 0.00571 $in.^4/in.$
r_{mean} = 2.05 in.
S_A = 972.2 psi

Strength Checks

Wall Crushing

$$FS_{WC} = \frac{2\sigma_y}{(SDR - 1)\sigma_{max}}$$

FS_{WC} = 1.5 ≥ 1.5

Wall Buckling

$$FS_{wb} = \frac{1.2}{\sigma_{max}} \left[\frac{E'/E}{SDR^3} \right]^{1/2}$$

FS_{wb} = 1.2 ≥ 1.5

Ring deflection (Modified Iowa Equation):

$$DX = \frac{D_L K W_c}{(EI / r^3) + (0.061 E')}$$

Change in diameter, DX = 0.15 in.
Ring deflection, DX% = 3.27 %

Pipe wall bending strain, ε_b.

$$\varepsilon_b = 6 \times \frac{t_{min} \times Dy}{D^2}$$

Dy = 0.147 in.
D = 4.09 in.

Bending strain, ε_b = 2.16 %

Allowable wall ring bending strain: from 4.2 to 8% (8% for 50 year design life) - [CPChem, 2003]

DX% = the ring deflection, %.
= 100(DX/D_{od})
ε_b = Bending strain, %;
Δy = Vertical deflection, in. = ΔX;
D = diameter = Mean diameter (D_{od}-t_{min}),

Written by: **A. Brown** Date: **7/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT** Project: **Malone Superfund Site** Project No.: **TXL0299** Phase No.: **02**

18"ƒ SDR-17 HDPE Riser Pipe (working stress)

Malone Superfund Site - Pipe Strength Design
Performed by: A. Brown

Input Parameters

Waste

d_c =	23	ft
γ_{avg} =	100	pcf

Pipe

SDR =	17	
D_{od} =	18.000	in.
t_{min} =	1.059	in.
E =	31,873	psi
σ_y =	1500	psi
D_L =	1.25	
K =	0.083	
k =	1.5	

Bedding Soil

E_s =	2600	psi
n =	0.19	

Calculated Parameters

σ_{max} =	16.0	psi
M_s =	2854	psi
E' =	4282	psi
W_c =	288	lb/in.
I =	0.09892	$in.^4/in.$
r_{mean} =	8.47	in.
S_A =	127.8	psi

Strength Checks

Wall Crushing

$$FS_{WC} = \frac{2\sigma_y}{(SDR - 1)\sigma_{max}}$$

FS_{WC} = 11.7 ≥ 1.5

Wall Buckling

$$FS_{wb} = \frac{1.2}{\sigma_{max}}\left[\frac{E'/E}{SDR^3}\right]^{1/2}$$

FS_{wb} = 12.5 ≥ 1.5

Ring deflection (Modified Iowa Equation):

$$DX = \frac{D_L K W_c}{(EI/r^3) + (0.061 E')}$$

Change in diameter, DX = 0.11 in.
Ring deflection, DX% = 0.60 %

Pipe wall bending strain, ε_b.

$$\varepsilon_b = 6 \times \frac{t_{min} \times Dy}{D^2}$$

Dy = 0.108 in.
D = 16.94 in.

Bending strain, ε_b = 0.24 %

Allowable wall ring bending strain: from 4.2 to 8% (8% for 50 year design life) - [CPChem, 2003]

DX% = the ring deflection, %.
= 100(DX/D_{od})
ε_b = Bending strain, %;
Δy = Vertical deflection, in. = ΔX;
D = diameter = Mean diameter (D_{od}-t_{min}),

Written by: **A. Brown** Date: **7/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT** Project: **Malone Superfund Site** Project No.: **TXL0299** Phase No.: **02**

18”ƒ SDR-17 HDPE Riser Pipe (back-calculated maximum stress)

Malone Superfund Site - Pipe Strength Design
Performed by: A. Brown

Input Parameters

Waste

d_c =	180	ft
γ_{avg} =	100	pcf

Pipe

SDR =	17	
D_{od} =	18.000	in.
t_{min} =	1.059	in.
E =	4,399	psi
σ_y =	1500	psi
D_L =	1.25	
K =	0.083	
k =	1.5	

Bedding Soil

E_s =	4700	psi
n =	0.28	

Calculated Parameters

σ_{max} =	125.0	psi
M_s =	6009	psi
E' =	9013	psi
W_c =	2,250	lb/in.
I =	0.09892	$in.^4/in.$
r_{mean} =	8.47	in.
S_A =	1,000.0	psi

Strength Checks

Wall Crushing

$$FS_{WC} = \frac{2\sigma_y}{(SDR - 1)\sigma_{max}}$$

FS_{WC} = 1.5 ≥ 1.5

Wall Buckling

$$FS_{wb} = \frac{1.2}{\sigma_{max}}\left[\frac{E'E}{SDR^3}\right]^{1/2}$$

FS_{wb} = 0.9 ≥ 1.5

Ring deflection (Modified Iowa Equation):

$$DX = \frac{D_L K W_c}{(EI/r^3) + (0.061E')}$$

Change in diameter, DX = 0.41 in.
Ring deflection, DX% = 2.29 %

Pipe wall bending strain, ε_b.

$$\varepsilon_b = 6 \times \frac{t_{min} \times Dy}{D^2}$$

Dy = 0.412 in.
D = 16.94 in.

Bending strain, ε_b = 0.91 %

Allowable wall ring bending strain: from 4.2 to 8% (8% for 50 year design life) - [CPChem, 2003]

DX% = the ring deflection, %.
= 100(DX/D_{od})
ε_b = Bending strain, %;
Δy = Vertical deflection, in. = ΔX;
D = diameter = Mean diameter (D_{od}-t_{min}).

Written by: **A. Brown** Date: **7/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT** Project: **Malone Superfund Site** Project No.: **TXL0299** Phase No.: **02**

12"ƒ SDR-17 HDPE Riser Pipe (working stress)

Malone Superfund Site - Pipe Strength Design
Performed by: A. Brown

Input Parameters

Waste

d_c = 23 ft
γ_{avg} = 100 pcf

Pipe

SDR = 17
D_{od} = 12.000 in.
t_{min} = 0.706 in.
E = 31,873 psi
σ_y = 1500 psi
D_L = 1.25
K = 0.083
k = 1.5

Bedding Soil

E_s = 2600 psi
n = 0.19

Calculated Parameters

σ_{max} = 16.0 psi
M_s = 2854 psi
E' = 4282 psi
W_c = 192 lb/in.
I = 0.02931 $in.^4/in.$
r_{mean} = 5.65 in.
S_A = 127.8 psi

Strength Checks

Wall Crushing

$$FS_{WC} = \frac{2\sigma_y}{(SDR - 1)\sigma_{max}}$$

FS_{WC} = 11.7 ≥ 1.5

Wall Buckling

$$FS_{wb} = \frac{1.2}{\sigma_{max}} \left[\frac{E'/E}{SDR^3} \right]^{1/2}$$

FS_{wb} = 12.5 ≥ 1.5

Ring deflection (Modified Iowa Equation):

$$DX = \frac{D_L K W_c}{(EI/r^3) + (0.061 E')}$$

Change in diameter, DX = 0.07 in.
Ring deflection, DX% = 0.60 %

Pipe wall bending strain, ε_b.

$$\varepsilon_b = 6 \times \frac{t_{min} \times Dy}{D^2}$$

Dy = 0.072 in.
D = 11.29 in.

Bending strain, ε_b = 0.24 %

Allowable wall ring bending strain: from 4.2 to 8% (8% for 50 year design life) - [CPChem, 2003]

DX% = the ring deflection, %.
= 100(DX/D_{od})
ε_b = Bending strain, %;
Δy = Vertical deflection, in. = ΔX;
D = diameter = Mean diameter (D_{od}-t_{min}),

Written by: **A. Brown** Date: **7/29/2014** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT** Project: **Malone Superfund Site** Project No.: **TXL0299** Phase No.: **02**

12"ƒ SDR-17 HDPE Riser Pipe (back-calculated maximum stress)

Malone Superfund Site - Pipe Strength Design
Performed by: A. Brown

Input Parameters

Waste

d_c =	180	ft
γ_{avg} =	100	pcf

Pipe

SDR =	17	
D_{od} =	12.000	in.
t_{min} =	0.706	in.
E =	4,399	psi
σ_y =	1500	psi
D_L =	1.25	
K =	0.083	
k =	1.5	

Bedding Soil

E_s =	4700	psi
n =	0.28	

Calculated Parameters

σ_{max} =	125.0	psi
M_s =	6009	psi
E' =	9013	psi
W_c =	1,500	lb/in.
I =	0.02931	$in.^4/in.$
r_{mean} =	5.65	in.
S_A =	1,000.0	psi

Strength Checks

Wall Crushing

$$FS_{WC} = \frac{2\sigma_y}{(SDR - 1)\sigma_{max}}$$

FS_{WC} = 1.5 ≥ 1.5

Wall Buckling

$$FS_{wb} = \frac{1.2}{\sigma_{max}} \left[\frac{E' E}{SDR^3} \right]^{1/2}$$

FS_{wb} = 0.9 ≥ 1.5

Ring deflection (Modified Iowa Equation):

$$DX = \frac{D_L K W_c}{(EI / r^3) + (0.061 E')}$$

Change in diameter, DX = 0.27 in.
Ring deflection, DX% = 2.29 %

Pipe wall bending strain, ε_b.

$$\varepsilon_b = 6 \times \frac{t_{min} \times Dy}{D^2}$$

Dy = 0.275 in.
D = 11.29 in.

Bending strain, ε_b = 0.91 %

Allowable wall ring bending strain: from 4.2 to 8% (8% for 50 year design life) - [CPChem, 2003]

DX% = the ring deflection, %.
= 100(DX/D_{od})
ε_b = Bending strain, %;
Δy = Vertical deflection, in. = ΔX;
D = diameter = Mean diameter (D_{od}-t_{min}),

LCS SUMP CAPACITY CALCULATIONS

Written by: **A. Brown** Date: **7/29/2104** Reviewed by: **S. Graves** Date: **9/2/2014**

Client: **ENTACT** Project: **Malone Superfund Site** Project No.: **TXL0299** Phase No.: **02**

LEACHATE COLLECTION SYSTEM (LCS) SUMP CAPACITY CALCULATIONS

GEOSYNTEC CONSULTANTS, INC.
TEXAS ENGINEERING FIRM
REGISTRATION NO. F-1182

SEALED FOR CALCULATION PAGES
1 THROUGH 6

1. INTRODUCTION

The purpose of this calculation package is to provide design calculations for the leachate collection sumps for the Malone Service Company Superfund Site RCRA Subtitle C Cell. Leachate will flow into each subcell sump from a leachate collection corridor, chimney drain, and the floor and sideslope drainage layers immediately adjacent to the sump. Leachate will be removed from the sumps via pumps.

In this calculation package, analyses are performed to demonstrate that the leachate sumps provide adequate leachate storage capacity so that a typically-sized submersible pump would not cycle on and off too frequently. The sump also effectively serves as a flow equalization element in the leachate collection system that stabilizes leachate flows from the subcell.

2. METHOD OF ANALYSIS

The proposed sumps for the RCRA Subtitle C Cell have the same geometry and are the shape of an inverted truncated pyramid with a square base. The formula for the volume of a truncated pyramid is:

$$V = \frac{1}{3}(a^2 + ab + b^2)H \quad \text{(Eqn. 1)}$$

where:

V = volume of truncated pyramid (i.e. sump);
a = the side length of the square top;
b = the side length of the square bottom; and
H = height of truncated pyramid.

The volume of the solid particles of the granular drainage material reduces the volume available for leachate storage. The effective volume of leachate storage in the sump is:

$$V_s = V * n \quad \text{(Eqn. 2)}$$

where:

V_s = effective volume of sump; and
n = effective porosity of granular drainage material.

The pump-on duration is equal to the amount of time it takes to pump down the leachate level from the pump turn on level to the pump turn off level. The pump-on duration is:

$$t_1 = \frac{V_s}{Q_{pump} - Q_{in}} \quad \text{(Eqn. 3)}$$

where:

t_1 = pump-on duration;
Q_{pump} = pump flow rate; and
Q_{in} = flow rate of leachate into the sump.

The pump-off duration is equal to the amount of time it takes for the sump to fill up from the pump-off level to the pump-on level. The pump-off duration is:

$$t_2 = \frac{V_s}{Q_{in}} \quad \text{(Eqn. 4)}$$

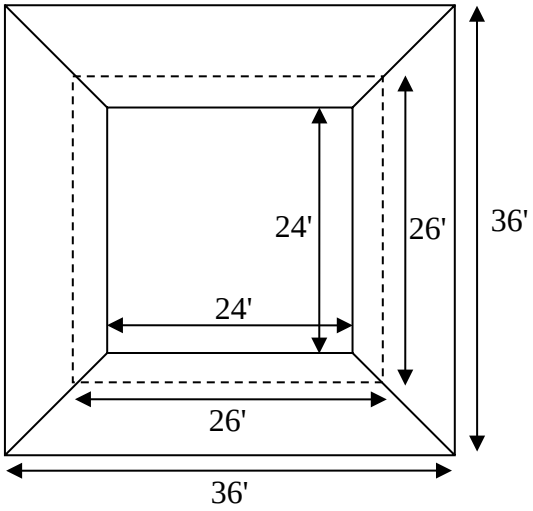
where:

t_2 = pump-off duration.

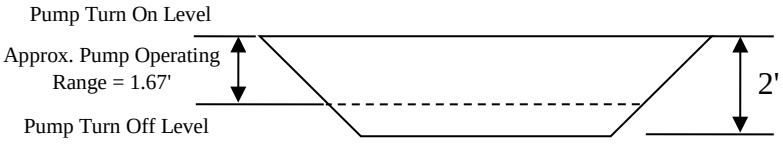
3. CALCULATIONS

3.1 Total Volume of Sump

The proposed leachate collection sump will be 2 ft deep and will have a 24 ft x 24 ft square base (based on 36 ft x 36 ft top dimensions) with a sideslope of 3 horizontal to 1 vertical (3H:1V) to meet the landfill floor, as shown in Figure 1 below. The submersible pump "turn off" level for pumps with the needed discharge rate is typically four inches above the base of the sump, so the assumed operating depth of the sump is 1.67 ft. It is assumed for these calculation purposes that the lower four inches of the sump will remain saturated and will therefore not contribute to the operating storage volume of the sump.



Plan View



Profile View

Figure 1. Proposed Leachate Collection Sump Configuration.

From the figure above, the operating parameters are:

$$a = 36'; b = 26'; H = 1.67'$$

Therefore, the total operating volume of the sump is:

$$V = \frac{1}{3}(a^2 + ab + b^2)H$$

$$V = \frac{1}{3}(36^2 + 36 * 26 + 26^2) * 1.67\ ft$$

$$V = 1{,}619\ ft^3$$

3.2 Effective Volume of Sump

The sump will be filled with granular drainage media with an approximate effective porosity of 0.32. Therefore, the effective volume of the sump is:

$$V_s = V * n$$

$$V_s = 1{,}619\ ft^3 * 0.32$$

$$V_s = 518\ ft^3 = 3{,}875\ gallons$$

3.3 Pump-on/Pump-off Duration

The peak daily flow rate of leachate into the sump (Q_{in}) was calculated using impingement rates provided in Table 1 of the Leachate Generation Rates and Head on Liner calculation package. The peak daily impingement rate for the most critical condition, initial condition Case IN, was 1,533 gallons per acre per day (gpad). Based on the impingement rate multiplied by the largest subcell tributary area of approximately 14.4 acres, the peak daily flow rate is calculated to be 22,079 gallons per day (gpd) (or 15.3 gallons per minute (gpm)).

For comparison purposes, the calculated average daily flow rate of leachate into the sump (Q_{in}) was calculated for the RCRA Subtitle C cell. The average daily impingement rate for the most critical condition, intermediate condition Case IN, was 150 gpad. The calculated maximum average daily leachate flow rate into the sump of the Subtitle C Cell was 1,037 gpd (0.72 gpm).

To evaluate whether the sump storage capacity, leachate generation rate, and pump cycling is reasonable, a submersible leachate sump pump with an operating capability (Q_{pump}) of approximately 20 gpm was assumed. This is not a specification for a required pump size, but is merely a check on whether typical pump equipment would be expected to be suitable for the RCRA Subtitle C Cell. For this assumed pump, for the peak daily case, the pump-on duration is:

$$t_1 = \frac{V_s}{Q_{pump} - Q_{in}}$$

$$t_1 = \frac{3{,}875\ gallons}{20\ gpm - 15.3\ gpm}$$

$$t_1 = 824\ min = 13.7\ hrs$$

and the pump-off duration is:

$$t_2 = \frac{V_s}{Q_{in}}$$

$$t_2 = \frac{3{,}875\ gallons}{15.3\ gpm}$$

$$t_2 = 253\ min = 4.2\ hrs$$

With a pump-on duration of 13.7 hrs and a pump-off duration of 4.2 hrs, a full on and off pump cycle is approximately 17.9 hrs. Most pump manufacturers recommend that the sump pump cycle time be more than 15 min, so a cycle time of 17.9 hrs is an acceptable cycle time for the peak daily condition.

For the average daily case, the pump-on duration is:

$$t_1 = \frac{V_s}{Q_{pump} - Q_{in}}$$

$$t_1 = \frac{3{,}875\ gallons}{20\ gpm - 0.72\ gpm}$$

$$t_1 = 201\ min = 3.3\ hrs$$

and the pump-off duration is:

$$t_2 = \frac{V_s}{Q_{in}}$$

$$t_2 = \frac{3{,}875\ gallons}{0.72\ gpm}$$

$$t_2 = 5{,}381\ min = 89.7\ hrs$$

With a pump-on duration of 3.3 hrs and a pump-off duration of 89.7 hrs, a full on and off pump cycle is approximately 93 hrs (3.9 days). Since most pump manufacturers recommend that sump pump cycle times be more than 15 min, a cycle time of 93 hrs is an acceptable cycle time for the average daily condition.

4. CONCLUSIONS

The storage capacity of each sump for the RCRA Subtitle C cell is calculated to be 4,366 gallons. Based on the assumption that the bottom 4-inches in the sump will be "stagnant" due to pump capabilities, the "pumpable" storage capacity of the sumps is 3,875 gallons.

Using the estimated leachate generation rates presented separately in the Leachate Generation Rates and Head on Liner calculation package, the calculations presented herein indicate that, for a given (assumed) submersible sump pump of 20 gpm, the proposed leachate sump has adequate storage capacity to provide acceptable pump cycle times considering peak daily and average daily operation rates.

This calculation does not require a specific size or capacity of the sump pump. It merely demonstrates the suitability of a typical size based on the anticipated flow rates and good practice for pump operation. Other pump capacities can result in adequate performance and may be selected by facility operations based on actual leachate generation rates and concepts consistent with those presented in this calculation package.